RON SHIP-BUILDING:

WITH

PRACTICAL ILLUSTRATIONS.

BY

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TO

THE RIGHT HONOURABLE

SIR JOHN SOMERSET PAKINGTON, BART.,

G.C.B., M.P., ETC., ETC.,

HER MAJESTY'S PRINCIPAL SECRETARY OF STATE FOR WAR,

PRESIDENT OF THE INSTITUTION OF NAVAL ARCHITECTS,

WHO, WHEN

FIRST LORD OF THE ADMIRALTY,

ORDERED THE CONSTRUCTION OF H.M. IRON SHIP OF WAR, "WARRIOR;" A STEP DESTINED TO HAVE AN IMPORTANT INFLUENCE ON THE NAVY AND THE SHIP-BUILDING TRADE OF THE BRITISH EMPIRE,

This Work

IS RESPECTFULLY DEDICATED

BY HIS OBEDIENT SERVANT,

JOHN GRANTHAM.

PREFACE.

In proceeding to enlarge this work, it has been deemed desirable, after mature consideration, to retain the original form, both in plates and text, and in a new edition to add some fresh drawings and a Supplement tracing the progress that has been made in Iron Ship-building up to the present time. The advantages of an iron ship, like steam navigation and railways, have become such established points, that the rising generation is scarcely aware that these things had no existence within the memory of many now alive, and that grave doubts were expressed, as each in its turn came into notice, whether iron could swim, a vessel be driven by steam, or whether steam could ever supersede horses for drawing carriages. In telling the story of each, the early steps by which the promoters fought their way to success become interesting.

The small work now again presented to the public contains the early history and the progressive stages of the science of Iron Ship-building, written in a form easily understood by all who desire to consider the subject, while the practical operations required in producing the ship are carefully described and illustrated.

Iron Ship-building has become as truly a b
of national industry as iron-making or cotton·
ning; and as in both these we are able to compet
almost all other nations in cheapness of produ
and thus bring a large portion of the requireme
those countries to our shores, so it devolves on
make every effort to keep up our character fo
best designs and modes of construction, as well
employ the best materials and workmanship.

It is trusted that this work will continue to pr
all the objects sought for in its publication.

April, 1868.

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ON

IRON SHIP-BUILDING.

INTRODUCTION.

In March, 1842, when President of the Liverpool Polytechnic Society, I made this interesting question the substance of the usual annual address to the members; on which occasion the Mayor, Dock Chairman, and several practical and scientific men were present. The object of the communication was to institute an inquiry into the advantages to be derived from employing iron as a material for building ships, and to compare such vessels with those built of timber. The paper was subsequently published in the form of a pamphlet, with plates, and was favourably noticed in all the publications of the day.

The time seems to be favourable for resuming the subject, and for laying before the public such further information as the last fifteen years have so amply provided.

In undertaking a work of still increasing interest, containing an inquiry of the greatest importance to this maritime country, I feel no apprehension in expressing the opinions which I entertain on the subject, as additional experience has only strengthened views so long

and so frequently advocated; and although I may, without assumption, lay claim to considerable experience in the details of the subject, it is one of such magnitude in its various bearings and ramifications, that I cannot, in again entering upon it, divest myself of some feelings of anxiety lest I should fail to do it that justice which its importance demands.

Some explanation may, in the outset, be expected from me, as to the opportunities I have had of forming an opinion on this subject; a few words only are necessary on this point. My attention was first directed to the subject in consequence of my father having, in 1824, caused a small iron steamer to be built to navigate the River Shannon, and the canals connected with it; from which time, a period of thirty-three years, my mind has been constantly directed to the subject, and I have possessed the most favourable opportunities for examining both timber and iron vessels of all descriptions, having been engaged in building several of the latter, some of which were on a large scale; and during the last fourteen years have designed and superintended many more, both for this country and abroad, an occupation in which I am still engaged. I have also been much assisted in my pursuit of this subject by my profession of Mechanical Engineer, affording me an extensive knowledge of the capabilities of iron, the mode of working it, and the proportions requisite to obtain any desired result.

I was amongst the first who received appointments from the Board of Trade as surveyors of iron steam-vessels—an office which the pressure of other engagements obliged me to resign a few years since.

It is not the intention in this paper to advance any-

thing on the subject of naval architecture *per se*, or to discuss the comparative merits of the forms of ships, further than as it is thought that iron is more or less suitable to carry out certain known principles, or as it may be the means of raising the character of our merchant shipping, long enthralled by an absurd system of registry laws.

In a work like this, intended for the perusal of all classes interested in the advancement of this peculiarly national subject, it would be unwise to encumber it with mathematical investigations or dry arguments, in attempts to prove the various positions herein assumed. I aim at nothing more than its practical and popular features, and will appeal only to experience and common sense. The leading object is to communicate to others that knowledge which has been gained by upwards of thirty years of observation, and to promote a branch of practical science destined to occupy a very important place in the future trade of this country; and to give Great Britain a pre-eminence in the construction of our merchant shipping, which a few years ago, it seemed not improbable, would be transferred to other countries.

It will be readily seen that this work differs widely from my former task, in one respect. It was then uphill work—it was sailing against the current; or, to use another figure, it was a small battalion, but lightly equipped, arrayed against an army of veterans. But steady determination, and consciousness that we who advocated the new system were right, has not left us unrewarded.

The change that has been produced in men's opinions is so great that it is difficult to realise what

was then felt; many who were then in active life have passed away, and made room for younger minds, less trammeled by early impressions, and more easily accessible to those changes that time invariably brings. Indeed, so great, and frequently so rapid, are these changes in our day, that as each successive discovery or improvement has so far run its course as to have become to our minds a necéssity—deprived of which we should lose an essential portion of our social inheritance—we are inclined to view with something allied to contempt, the want of intelligence which so long kept men in ignorance of the object now so plain; or to feel displeasure at the dulness of those who, when first the subject was revealed to them, were reluctant to receive it, or even opposed its introduction and progress.

Experience and reflection will, however, make us more reasonable, and enable us calmly to wait for time to have its usual effect.

We see also an apparent dispensation in Providence, that discoveries for the benefit of the human race should spring up, and that facts long hidden should be developed, in order, either to compensate for some failing resource, to provide for the increasing wants of large populations, or to afford channels for conveying a knowledge of the truth, or the blessings of civilisation to distant lands, where darkness and ignorance have before reigned.

The science of navigation, more than any other, takes the lead for its importance in relation to this and similar developments; and Great Britain, of all countries, can appreciate its value, having reaped great benefits from its advancement, and being in its turn a *blessing to others.*

Our island home and sea-girt land at all times forces this science on our attention, and leads the mind to practical efforts; self-interest at one time, and self-protection at another, urging us to strive for progress and pre-eminence.

The steam-engine of later years has made a new era in this important subject, and now, still later, the employment of iron as a material for ship-building is slowly but surely adding another link in the chain of modern improvements.

This innovation, as many have esteemed it, includes some of the points just referred to. Timber, for ship-building, has become scarce, and if required in large quantities must be nearly all imported. Our population has increased and so have our wants, giving to trade a stimulus unknown to the world before; requiring a great increase in the size and number of our vessels, and the extraordinary development in our moral and social condition urges us to communicate to mankind through the means of improved navigation, and increasing trade, the stores of knowledge which we have acquired.

In the following remarks on iron ships and ship-building, the various branches of the subject will be placed under their respective heads, commencing with the

EARLY HISTORY OF IRON VESSELS.

It is a common error to suppose that vessels have but recently been constructed of iron, and that the principle is only advocated by a few whose interest, as *workers in iron, leads* them to promote it. Some there

are, naturally enough, who still view the subject with distrust, and regard it as one of the visionary schemes of this wonder-working age, which will soon be relinquished and forgotten. But it is easy to show that the construction of iron vessels is not an invention of recent date; that the value of iron as a material for ship-building has long been known; and that it has for many years been making a sure, though slow, progress towards the improved state it has now attained.

The first traces that I can discover of the construction of iron vessels are of those built for the canals of this country. The following paragraph was cut from a publication bearing date July 28, 1787, and written from Birmingham.

"A few days ago, a boat built of English iron by J. Wilkinson, Esq., of Bradley Forge, came up our canal to this town, loaded with 22 tons and 15 hundred-weight of its own metal, &c. It is nearly of equal dimensions with other boats employed upon the canal, being 70 feet long, and 6 feet 8½ inches wide; the thickness of the plates with which it is made is about five-sixteenths of an inch, and it is put together with rivets, like copper or fire-engine boilers; but the stem and stern-posts are wood, and the gunwale lined with the same; the beams are made of elm planks. Her weight is about 8 tons; she will carry, in deep water, upwards of 32 tons, and draws 8 or 9 inches of water when light."

These vessels began to be more generally used as far back as fifty years since, and it is stated by those who have a good opportunity of knowing, that some of them made at a very early date may still be in existence. During the meeting of the British Association

in Glasgow in 1840, after a paper had been read on the subject of iron vessels, several gentlemen communicated facts, which had come within their own knowledge, with respect to their early introduction. A friend, in writing on this subject, states that a gentleman in Staffordshire was at that time cutting up some iron vessels which had been at work twenty-eight years. My late partner, Mr. Page, was engaged in building several canal boats of iron, upwards of forty years since; and I have myself seen iron vessels in Staffordshire, of a great age, but the precise date of the construction of which could not be ascertained. These facts are interesting, not only as proving that the subject has long been under the attention of practical men, but as evidence of the strength and durability of iron vessels, points which will hereafter be more fully alluded to.*

* This note, received from my friend Mr. T. Jevons, deserves insertion here, as further evidence of the early introduction of iron vessels.

Liverpool, 19*th March*, 1842.

DEAR SIR,—Understanding that you are about to publish a history of the application of iron to the building of boats and ships, and having been the first individual, I believe, that ever launched an iron boat on salt water, I take pleasure in communicating the particulars of the earliest attempts to introduce iron for ship-building purposes, and which, I trust, will not be altogether uninteresting.

In August, 1815, I launched a small iron boat, which I fitted up as a pleasure boat, and frequently sailed in it on the river Mersey. It was built by Mr. Joshua Horton, of Tipton, near Birmingham, but fitted up in Liverpool by the late Mr. Roger Hunter, and the late F. J. Humble. When not in use, this boat was put up in the Duke's Dock, where it was open to the gaze of any passer by; and, not being what a sailor would term *ship-shape*, owing to its being built inland, it was rather a curiosity. Its buoyant powers, however, and the remarkable ease with which it maintained its way, when once put in motion, attracted the notice of many. After having been a spectacle for the public for many weeks, this boat disappeared, and no trace of it could be discovered for a long time; but, on the next occasion of the Duke's Dock being let dry, it was found crushed up and deeply imbedded in

The first iron *steam* vessel, and the first that ever put to sea, was built by the Horsley Co., of Stafford·shire, for the Seine, and called the *Aaron Manby*

earth at the bottom of the dock. It is impossible that this boat could have been sunk without the use of some powerful mechanical aid, or of tools of some description; and the conclusion therefore is, that it was injured for some malicious purpose. The boat thus ruined was got up out of the dock and sold for old iron, returning to me a fair proportion of its original cost.

The loss of this boat turned my attention to the practicability of making an iron boat which could not be sunk by any ordinary means, and, having matured my ideas on the business, I sought the means of putting them to a practical result; and for that purpose, in the year 1817, I made an agreement with the brother of Mr. Horton, the builder of my first boat, with the view of his settling in Liverpool, as an iron ship and boat builder. A suitable yard was taken, and a rent paid upon it for six months; but this project was frustrated by the death of Mr. Horton, by typhus fever, before he could remove to Liverpool. This disappointment checked my efforts for a time; but, determined not to let the subject rest entirely, and believing my invention a valuable one and worth while securing to myself, I lodged a Caveat in the Patent Office, in April, 1818, with a view of taking out a Patent, and thereupon proceeded to have a model constructed of a *life-boat*, to be built of *iron*, and which from its peculiar form would possess to a great degree the property of righting itself, in case of being blown over by a squall of wind, and also of baling itself of any water it might ship from this or any other cause. This model, which for convenience sake, was made of copper instead of iron, but which substitution of metal of course made no difference in displaying the principle of my invention, was exhibited in the Under-writers' Room at Liverpool, and its properties allowed to be tested in a tank of water in which it floated for that purpose.

The Caveat which I lodged in the Patent Office, I renewed several times; but, circumstances not favouring my again attempting the building of iron boats and ships for my own benefit, I at length sent my model boat to the same individual who had built my first boat, and from that model was constructed the second iron boat that ever floated on the salt sea, and which boat was a complete life-boat.

In September, 1822, I wrote a description of this life-boat, which was published in the *Kaleidoscope*, vol. iii. p. 105, and a reprint of it was afterwards given by Mr. Egerton Smith, in his publication, entitled *Desultory Suggestions for Prevention from Shipwreck;* and as that description points out many of the superior properties of iron for the *purpose of ship-building,* which have since been practically proved to

fter the name of the projector. I have been favoured y Mr. Manby* with the particulars relating to this essel, which are very interesting as recording the igin of iron steam vessels. He states in his communication, dated 19th February, 1842, that under a itent which was taken out in France for iron steam ›ats, in 1820, he, with his friend Captain (now Admiral r Charles) Napier formed a Society, and immediately gan to construct their first boat at Horsley, but ring to some circumstances connected with the parties Paris, she was not completed till the end of 1821. ie was then sent to London in parts, and put together dock. She took in a cargo of linseed and iron stings, and Captain Napier took charge of her, and vigated her from London direct to Havre, and thence Paris, without unloading any part of the cargo, she ing the first and only vessel of any description that r about thirty years afterwards sailed direct from ondon to Paris. Mr. Manby continues—"Some time ter, I built another iron steam vessel of the same

true, although only yet, I believe, known to but very few, I beg ve to enclose you a copy.

The iron life-boat met with no better treatment than the first iron at; for, having been lost for a long time, it was at length discovered bedded in sand at dead low water of a remarkably low spring tide. e cause of its so lying being manifestly occasioned by some holes lled into her chambers by some unknown hands. But this boat ving been found again, and not otherwise materially injured, was paired and sold for use in the West Indies, where no doubt, it is still ing good service to its owner.

I am, dear Sir,
Yours very truly,
THOS. JEVONS.

John Grantham, Esq., Liverpool.

* *C. Manby, Esq., F.R.S.,* son of Aaron Manby, Esq., for many years *retary to the Institution of Civil Engineers.*

description, with a few alterations, at Horsley; but, owing to the navigation laws in France, she could not be admitted, and was obliged to be shipped in parts, and I put her together at Charenton, near Paris, where I had then established iron-works, and where I subsequently constructed two other iron steam-boats, the whole for the navigation of the Seine. They continued prosperously at work till 1830, when, owing to the revolution, and some disputes among the shareholders, they were sold to a new society. In this new society I had no further interest, but they continued navigating up to the period of my quitting France, and I believe are all at work at the present time. From 1822 to 1830 the hull of the *Aaron Manby* never required any repairs, although she had been repeatedly aground with her cargo on board."

This vessel does not appear to have been very fast, but excited considerable attention, as will be seen by the following extract from "Le Constitutionnel," of 13th of June, 1822:—"Le bateau à vapeur en fer, l'Aaron Manby, Capt. Anglais Napier, est arrivé hier, Lundi, à huit heures du soir au Port St. Nicholas, avec un chargement de graine de tréfle, qu'il avait pris à Rouen, et de quelques pièces de fonte et de mecaniques, venant d'Angleterre. Le bateau Français à vapeur, Le Duc de Bordeaux, arrivé de Rouen samedi au soir, avec un chargement complet qu'il n'avait pu mettre à terre en entier, était parti au port à quatre heures du soir pour aller à la rencontre du bateau Anglais qu'il a atteint à la hauteur de Saint Cloud, en face des cascades. Ils sont partis ensemble, de la pointe de L'Isle Seguin, et le bateau Français, dont la manœuvre *est visiblement* supérieure, est arrivé au Port St.

Nicholas quarante minutes avant l'Anglais. Les curieux ont été, pendant, toute la journée, visiter les deux bateaux."

The next iron steam vessel was built by the Horsley Co., under my father's superintendence. This vessel was commenced about the year 1823; was put together in this port, and, after a series of delays, crossed the Channel in 1825, and proceeded to her destination, Lough Derg, on the River Shannon. She was kept actively at work for many years, and now, after a period of 34 years, is still afloat, though not at work. A correspondent writing in June last, states, that her engine and boiler are bad, and her decks and timber work decayed, but that "the hull is the best part of her." This vessel was the origin of the extensive and spirited company which for many years occupied that splendid river, and which conferred important benefits on the large tract of country through which the Shannon flows. My friend Mr. C. W. Williams, Managing Director of the City of Dublin Steam Packet Company, at this time directed his attention to the subject of iron vessels. With his usual discernment he foresaw the advantages to be derived from this source to steam navigation, and has ever since been a steady advocate of the principle. It was at his recommendation that the Shannon Company continued to construct iron steamers for their trade. The vessel above described was named the *Marquis Wellesley*, the Lord Lieutenant of Ireland at the time. She was of the form called the "twin boat," having the paddle-wheel in the centre—a plan since then more than once revived as a *new invention*.

Messrs. Fawcett and Co. contracted for a second

vessel of the same form, in 1829; the first iron steamer built in this town.

Much interest attaches to the next iron steam vessel of which I have any record. She was 70 feet long by 13 feet beam, and 6 feet 6 inches deep. She was built by Mr. Macgregor Laird about the year 1831, and was to have received some experimental machinery, but was afterwards fitted with an ordinary condensing engine of 16-horse power by Messrs. Fawcett and Co. She was employed as an assistant vessel to the African Expedition, which was conducted by Mr. Laird* himself and the two Landers, whose names have ever since been honourably identified with researches on the Niger—a pursuit that may yet lead to most valuable results.

This little vessel, called the *Alburkah*, drew only 3 feet 6 inches water, and her seaworthiness, during her long voyage, entirely destroyed the fallacy of the danger of going to sea with so light a draught of water. She made two ascents of the Niger, and was afterwards beached at Clarence Cove, where her ribs are still visible.

The success of this little vessel led to the building of the *John Randolph*, of 250 tons, for Savannah, in 1833, and the *Garry Owen* for the Lower Shannon, in 1834, both by Mr. John Laird, who at this time was regularly engaged in building iron vessels.† The *Garry Owen* was the first iron steamer which had a regular arrangement of water-tight bulkheads, the in-

* Mr. Macgregor Laird has been for several years the Managing Director of the African Mail Company.

† Mr. Laird has, up to this time, built the large number of 225 vessels, having an aggregate of 88,000 tons, and 16,200 horse power.

vention of Mr. C. W. Williams. Such appliances are now deemed essential to all iron vessels, and their adoption is enforced by Act of Parliament. At this time, also, Mr. Laird built two iron steamers for the River Euphrates, for the expedition headed by Major (now General) Chesney, one of which vessels, the *Euphrates*, is still at work on the Indus.

The *Rainbow*, of 580 tons, was built by Mr. Laird, in 1837, and was employed in the Havre and London trade, carrying goods and passengers with great success.

The *Brigand*, large paddle-wheel steamer, was built by the firm with which I was connected, shortly after this, and was one of the first that ran regularly as a trading vessel in the Irish Channel.

In 1839, the *Nemesis* and *Phlegethon* were also built by Mr. Laird for the Honourable East India Company; the former of 660 tons, and the latter of 570 tons. These vessels are entitled to particular notice as being the first iron steamers that were engaged in fighting the battles of their country, and took a conspicuous part in the Chinese war of 1842. They gave early proof, of what has been since often confirmed, of the power of iron vessels to bear the concussion of heavy guns fired from their decks.

During this period, and for some years previously, I watched with the greatest interest the progress of iron vessels, feeling convinced that they must ultimately supersede those built of timber. Many others have now, for a long time, carried on the business, and numerous iron steamers and iron sailing vessels of large tonnage are now afloat, or building. Great numbers of iron steamers are plying on the Thames, the Mersey,

the Clyde, and on nearly all the continental rivers. Large fleets are to be seen navigating every sea, the property of every nation; the most satisfactory proof of their success.

The *Princess Royal* iron steamer, for several years running between this port and Glasgow, built by Messrs. Tod and M'Gregor, a most successful vessel of 800 tons, long attracted attention for her great speed.

When this work was first published, a few iron sailing vessels had made voyages both to the East and West Indies; and I believe that the statement of facts which I then made on this subject, and the description of the mode of construction which I then gave, were instrumental in correcting the false impressions at that time abroad on the subject, and in promoting an object which is of the utmost importance to our national and commercial interests. The *Ironside* was the first iron sailing vessel of any magnitude that was employed for sea voyages, and gave promise of the success which has now been so fully confirmed.

Mr. Fairbairn, of Manchester, very early took an interest in iron vessels, and was a party to a series of experiments made at Glasgow in which iron vessels were employed.

A proposition was made in 1838 by Mr. Holmes, C. E., to construct large iron steamers for the communication, *viâ* the Red Sea, to India. Some of his calculations as to the profit to be derived from this speculation are very doubtful; but his general views appear to have been correct. He certainly deserves credit for his exertions, which, however, seem to have been unsuccessful. His report would receive much more attention now than it did at the time of its publi-

cation, as it is very evident that he judged correctly as to the comparative merits of wooden and iron vessels for long voyages. Several men of experience gave evidence in favour of iron vessels before the committee appointed to investigate the subject.

Among the best early publications relating to iron vessels was a paper written for the "United Service Journal," in May, 1840, by the late Mr. Creuze, of her Majesty's Dock Yard, Portsmouth, and author of the able article on ship building in the last edition of the "Encyclopædia Britannica." This communication was suggested in consequence of the injury sustained by the *Nemesis*, on the rocks off Scilly. Having put into Portsmouth for repairs, she was there seen and examined by Mr. Creuze. I shall occasionally submit extracts from this paper, it being the production of a gentleman who evidently possessed a scientific knowledge of his subject, and was fully alive to all the difficulties which are to be encountered in naval architecture.

Monsieur Dupuy de Lôme, connected with the French navy, published a work on iron ship-building, which showed a just and intelligent appreciation of the principle; his knowledge of the subject, however, seemed nearly confined to what he saw in this country, and therefore did not supply any fresh views to the English reader.

The *Great Britain* iron steamer built at Bristol, was at the time the boldest effort in iron ship building, and formed the most remarkable feature in the history of this important science.*

It would now be difficult to follow the history of

* The *Great Britain* was in progress when my first work was written, and some details of her construction were given at that time.

individual ships. The science which had been thus established, was pursued most actively in the Clyde, the Thames, the Mersey, and latterly in the Tyne; and no port of any magnitude but can claim now a share in the work. Builders can number the vessels built by them by tens and hundreds, and to attempt a list of the aggregate number built up to this time, in the United Kingdom, would be a work of no little difficulty.

The encouragement given to iron ship-building in France by the admission of iron for that purpose duty free, has been the means of producing a large number of very fine vessels. In the extensive yards at Toulon, under the management of the Messrs. Taylor, I have seen as large and well-built vessels as any builder in England can produce.

For some years past iron vessels have been built in ports in the Baltic, and throughout the continent of Europe they are probably everywhere to be found.

During the late war with Russia, some of our iron vessels that had been seriously injured by collisions, were as neatly repaired at Constantinople as they would have been done in our own yards; and the newspapers now tell us of an iron screw steamer that is leaving this country for the whale fisheries.

But strange as it may appear, our shipowners long resisted the conviction that iron could be advantageously applied for building *sailing* ships required for long voyages. Some, however, are now yielding to the opinions we have so long urged, and many large and splendid specimens of naval architecture, in the form of iron sailing ships are owned in every large port, but especially at Liverpool.

But the climax in the history of iron ship-building

is reached in the *Leviathan* now building in the yard of Messrs. J. S. Russell & Co., Millwall. We cannot expect for many years, if ever again, to have occasion to notice a more stupendous illustration of all that can be said or argued in favour of iron as a material for ship building, than the *Leviathan* is likely to afford. We may already point to her as a proof of the facility of producing the largest structures with that simplicity and unity of design, and with that precision, that should ensure for iron ship-building a confidence which need not be disturbed, and a character that cannot be questioned. Of her strength we have as yet no proof, though of this there can be little doubt.

Except, perhaps, as a matter of historical interest, it would not here be necessary to refer to this vessel in any other of its features; my object, in this work, being simply to point out the peculiar suitability of iron for the construction of ships of any size; but I feel unwilling in this case to omit an enumeration of some of the wonders which are necessarily involved in it. Neither does it come within the scope of this work to give any opinion as to the probable speed she is likely to attain, nor, as to the commercial prospects of this peculiar vessel. It may be asserted in general terms, that the speed of vessels increases with the increase of their dimensions; and that commercially iron ships, and particularly iron steam vessels, are much superior to timber-built ships, for reasons which will be more fully dwelt upon as we proceed.

This vessel is a source of great interest, and it is the intention further on, to give some of the details of the hull, and also to illustrate the form and mode of *construction by drawings.*

It is proposed in another place to show the connection between the subject of iron ships, and the progress of steam navigation; the advantage of iron under this aspect being too palpable to allow men to hesitate as to its adoption.

The employment of iron, as a material for ship building, having excited much attention, and its evident advantages in several particulars, for this object, led men who could not shake off their feelings of preference for the old system to substitute it partially, and apply it only to such parts as they supposed it to be best adapted for. Some attempted to use plates for the outside shell, to be stiffened by timber frames; others more successfully made the frame-work of iron, and still retained timber for the planking. A patent* was taken out about fifteen years since, to construct canal boats with the ribs made of angle iron, and the planks of timber, and some small vessels were built on this plan. Another patent was taken out a few years ago for the same object, and two ships of considerable size were built by the patentee.† These vessels exhibited the principle to great advantage, and have proved very successful. It would, perhaps, not be difficult to show that the iron frames of these vessels were expensive, and that the number of binding plates and other fastenings necessary to strengthen them would go far towards building a ship entirely of iron. But upon this point it would be better to leave experience and time to do their work in testing the merits of the system, as it is possible that for some purposes it may have advantages.

* *By* William Watson, Esq., of Dublin.
† *Mr.* W. Jordan, of Liverpool.

CONSTRUCTION OF IRON VESSELS.

WITH a view to the better elucidation of the subject, I now proceed with a description of the ordinary method of constructing iron vessels. In doing this, it may be considered, by those engaged in the same pursuit, that I am laying open to the public eye the secrets of the business, and encouraging others to enter into competition with them. But although the principle of iron vessels can no longer be considered new, there is still much room for the exercise of ingenuity and practical skill; and it is desirable that the public should be made acquainted with the general principles on which we proceed, as the best means of giving confidence to the shipowner and extending the demand for vessels of that material. It would conduce to our mutual interest to communicate to each other more freely the results of our experience, in order to insure as much as possible the introduction of every improvement, and thereby promote the employment of iron-built ships.

It is the intention to describe only the *ordinary* mode of construction, as now generally adopted, and not attempt to suggest new and untried plans, although it is easy to conceive that the subject admits of much improvement.

KEELS.

It may be observed, before proceeding, that the use *of keels in iron as well* as in wooden ships is by no

means essential to their construction. They become less necessary as vessels increase in length, and as steam power is employed to assist or supersede the use of sails.

They however possess some advantages, and have few disadvantages, and are therefore generally applied to vessels of all classes.

As commonly used, they add to the strength of the bottom, although the same strength may be attained by other means; they form a channel for bilge-water in very flat vessels, and enable pumps, when led into them, to draw off the water more clearly from the ship. They form also a lateral resistance to the water, and thus tend to preserve the straight direction of the ship when pressed by her canvas on the beam. The first blow received by a ship, when striking rocks, is frequently on the keel, and the shock thus partially broken, the vessel is sometimes preserved from greater damage.

In the early introduction of iron ships, wooden keels as well as wooden stems and stern-posts were sometimes adopted; but the system was imperfect and dangerous, especially for keels. More than one vessel had her false keel knocked off, and the bolts by which it was secured to the hull being broken, admitted the water, and nearly sunk them.

Plate I. exhibits some of the forms of keels which have from time to time been generally used. Figs. 1, 2, are the section and plan of a keel patented by the Oakfarm Iron Company. It was rolled with much success, and was an interesting specimen of what may be done by machinery. Its principal disadvantage arose from the short lengths in which it was rolled,

and the difficulty of welding such a peculiar form into long lengths. It was made of three slabs previously prepared in separate rolls, and then finally welded at the points *a*, *b*, by passing the whole together through other rolls, and thus took the form shown in the drawing. I have not heard of its being used for several years.

Figs. 3, 4, 5, are the sections and plan of a keel nearly corresponding in form to the last. It has, from the early introduction of iron ships, been occasionally adopted, and I have lately designed several vessels where it has been applied. It has the advantage of adding but little to the draught of water of the vessel, and forming a channel for the pumps in very flat vessels. Being, however, exposed to the action of sand and gravel in very shallow water, it should be nearly double the strength of the bottom plates. This form of keel is made of good tough iron, about eight to ten feet long, bent on a mandril, and then welded into long lengths from thirty to forty feet. These pieces are united by strong plates (fig. 4), but in consequence of their necessary thickness forming a partial obstruction to the bilge-water, it would be much better if the whole keel could be welded into one piece. This has been done in some cases.

Figs. 6, 7, exhibit the section and plan of what is called a "bar keel." This is made of massive bars, in lengths varying from twenty to forty feet, united by scarphs, as at fig. 7. To obtain the form shown by the section of the bar, and to make the grooves suitable to receive the plates, as at A, each piece went through the *tedious process* of planing. The necessity for this expensive plan not being very apparent,

the usual form now given to bar keels is represented in figs. 8, 9, 10. This keel is made the same as the last, but without the groove for the plates, and is found perfectly efficient. It is recommended in Lloyd's Regulations that the floors should rest on the bar of the keel, as at A, fig. 8, and a hole is cut in the plate of the floors for the bilge-water; but in cases where the bar is kept a few inches from the floors, as at fig. 9, there is a sufficient limber for the water without wounding the floors.

Fig. 11 is again the same form of keel, composed of plates instead of a solid bar. The advantages sought by this plan probably are cheapness and facility of construction, especially in shifting the butts. The solid bar is, however, more generally adopted, and appears to have many advantages.

As regards the principle of a bar keel, a few general observations appear necessary. It is most applicable to sailing vessels, which require the use of deep keels to preserve their leewardness; or to vessels where a light draught of water is not essential. The disadvantage of these keels in very flat vessels, where the draught of water must be kept as small as possible, is that the plates of the garboard strake are necessarily bent at a sharp angle, and thus rendered liable to crack.

The relative dimensions of the different parts of iron ships will be given in other places.

STEM AND STERN-POSTS.

Various plans have been adopted in constructing the stem and stern-posts of iron vessels. Formerly

the stem was formed by a plate so bent as to have the outward appearance of the stem of a wooden vessel; but this plan was defective and dangerous. The stem of a vessel so constructed is liable, should she strike any hard body, to become indented; and, from the injury necessarily sustained by the plate in the process of bending, it is liable to crack. A better and much simpler plan is now adopted (see fig. 12). A bar—a piece of strong flat iron—is fashioned to the required form of the stem, extending from the upper deck to a few feet along the keel, to which it is scarphed. The plates which form the sides of the vessel extend to the fore part of this stem, and the whole are firmly riveted together. Vessels built with the stem so constructed have exhibited wonderful instances of strength, when coming in contact with hard bodies, and even with stone piers.

The bar of which the stem is composed has sometimes been grooved, as before described, for the keel, as shown in fig. 13; but this form has likewise given way to the more simple one above mentioned. The stern-post, like the stem, is now always made of a forged bar of iron, a section of which is shown in fig. 14. The rudder is suspended either by projections welded on to its after side, as shown in dotted lines; or braces are riveted to it, something similar to those in wooden vessels. A more particular description will be given hereafter with respect to the stern-posts of screw steamers.

FRAMES AND FLOORINGS.

The frames of an iron ship are those portions which correspond to what are aptly termed the *ribs* of a

timber ship, but vary in their character very materially. The frames, or ribs, of wooden ships, especially of large ones, are composed of many parts, occasioned by the impossibility of getting timber of the dimensions and forms requisite for such a structure. There is first, the floor, then the first, second, and third futtock, then the top timber. Each of these must have a long scarph, or have the joint crossed by a second frame, involving a large surplus of timber, simply for the purpose of uniting one piece to another. But the rib or frame of an iron ship is of a more simple form, having little or no waste in scarphs, and, by a short process hereafter described, easily bent into the required form. Each frame is designated by the terms side-frame and flooring. The former is represented in Plate II., figs. 1, 2, 3; and the latter in figs. 4, 5, 6, 7. The frame is first formed by a plain bar of angle-iron,* made in one, two, or three lengths. Where three pieces are used, a junction is made at the bilges by an overlap of four or more feet, giving additional stiffness to that part. The floors, which extend across the bottom, are strengthened by plates placed on their edges, riveted to angle-iron, Plate II., figs. 4, 5. On the upper edge of each of these plates is another angle-iron, extending across the ship, a short distance up the sides. Sometimes in shallow vessels angle-iron bars, of larger dimensions, are substituted for the plates, and in some cases, especially under the engines of steam vessels, where the strain is great, another bar is added, both to the upper and lower edge of the flooring, as in figs. 6, 7.

To the side-frames are generally added reverse angle-

* *The forms of angle-iron* used in ship-building will be seen in Plate V.

iron, as at A, fig. 3. In most vessels these are only applied to the alternate frames, and serve the double purpose of giving additional strength to the frames, and of providing a suitable surface by which to secure the iron stringers, or wooden linings, required in finishing the vessel.

Fig. 8 is the form sometimes given to bilge keels, as afterwards described.

In Plate III, figs. 1, 2, are represented two other kinds of floorings, and the keelsons which are connected with them. These are formed by plates and angle-iron, as above described; but in fig. 2 the floor-plate is divided in the centre, allowing the keelson to run from end to end of the ship in an unbroken line.

This floor is united to the keelson by angle-iron at A, and again on the top sides by the plates B, and the angle-iron C, all running fore-and-aft the ship, and all riveted firmly to each other.

On Plate XV. is shown another plan of flooring, nearly allied to the last, but having the addition of a keel. A broad and massive plate, about 1½ inches thick, is provided, of sufficient depth to form a keel, and to extend to the top of the flooring. Each plate is made as long as possible, and jointed by two broad plates well riveted to it. The garboard strakes are fitted to it, as in the ordinary bar keels, and the floorings are attached to it as in Plate III., fig. 2; the whole is then united into one body by the top plate, A, securely riveted to each flooring.

In connection with this feature in iron ship-building, I may notice a plan adopted in the *Great Britain*, where the bottom frame-work of the ship is composed of a succession of fore-and-aft ribs, the transverse

frames consisting of short pieces of plates and angle iron. Some idea of this system may be gathered from the section of the *Leviathan*, given in Plate XXIII., though in this case the transverse ribs have been omitted.

Keelsons, Sister Keelsons, and Bilge Pieces.

These are all portions of a ship's frame, in immediate connection with the floorings, and are represented in the same drawings.

The centre keelsons are there shown in three forms. The first as a box keelson, formed of plates and angle-iron, running across the top of the floorings, to which it is united.—Plate II., fig. 4.

The second, as in Plate III., fig. 1, consists of short plates let down between the frames, and extending above them to A, and called the intercostal* middle line keelson; this is also united to the floors by angle-iron at B, and on the top edge by angle-iron, as at C.

The third plan, fig. 2, consists of a centre plate before mentioned, running fore-and-aft the ship. This form is applicable to vessels having no keel, but having a strong plate, as at D, to which the keelson is united by angle-iron at E.

Sister keelsons, D, fig. 1, are generally formed similarly to the centre keelson shown in the same plan; they serve the double purpose of giving strength to the ship, and of checking the wash of the bilge water when the ship rolls at sea. Bilge pieces, or stringers, of angle-iron of various forms, are placed at intervals along the bilges, and up the sides of the ship; one of

* "Intercostal," a term introduced in Lloyd's regulations for iron ships.

these is shown in section, Plate II., fig. 8. Others are merely made of two bars of angle-iron riveted together, as shown in the general plans of vessels, Plates XIII., XIV.

Beams.

These are next formed; they possess many advantages over timber beams, which are not only more bulky, but require large knees of timber or iron to secure them at the ends. The iron beam is made of different forms, and as the art of ship-building progresses, attempts are made to roll iron of the exact form required, but this has not yet been accomplished to any great extent. The forms usually employed are shown on Plate III.

Figs. 3, 4, represent a beam made of a single bar of angle-iron, having the long side downwards; this is secured to the frame of the ship by an angular plate, A.

Fig. 5 is the same angle-iron, stiffened by a reverse bar, riveted to it.

Fig. 6 is formed by a plate, having one or two light bars of angle-iron on the upper edge.

Fig. 7 is a bar of iron rolled for the purpose, and called bulb iron, to the upper edge of which angle-iron bars are also attached.

Figs. 8, 9, represent a form of beam iron introduced a few years ago, but not extensively used, as the iron masters were unable to produce it, except in short pieces, which caused much expense and trouble in welding; it is now again introduced, but in greater lengths, and if not too expensive, will soon doubtless be more generally applied.*

* This form is the subject of a patent taken out by Messrs. Kennedy & Vernon, of this town.

A further improvement has been introduced in the formation of iron beams, which gives a neat finish to the work; this is shown in fig. 8, and represents the end of the beam, which is split, and the lower part, A, bent downwards, leaving the open part, B, into which an angular piece of plate, shown by the dotted lines, is welded, and is a substitute for the usual knee plate, as shown in fig. 3. In the upper flanches of these beams holes are punched at short intervals, and wood screws are driven up from below into the deck plank, to secure the latter to the beams. Bolts and nuts are sometimes used, the bolt head being sunk below the surface of the plank, and the hole plugged up to keep it water-tight. A bolt of each kind is seen in dotted lines, marked A, B, figs. 10, 11.

GUNWALES AND STRINGERS.

The gunwale is the point of junction between the sides and the upper deck. It is a part of the ship at all times requiring great care and skill, but in iron ships demands peculiar attention, as in no part have they been more defective.

There are two principal causes for this. First, sufficient care has not been taken to unite the wood-work to the iron, hence a serious leakage has resulted; and secondly, the construction of the iron stringers, or deck-plates, and other fastenings has been very deficient in strength. The recent attention given to iron structures in the form of wrought-iron tubular bridges, has thrown much light upon the best proportions to be given to iron girders, of which an iron ship is one modification; the experiments lately tried have

shown that great strength should be given at the upper edge, and clearly prove, what indeed has long been evident, viz., that, to make a sound ship, the gunwale must be very differently constructed from what it generally has been.

Several plans of the forms in common use are given, and will now be described, beginning with that generally applied to small vessels.

Plate III., figs. 10, 11, show the gunwale of an iron ship in its simplest form. It consists of a bar of angle-iron, riveted to the upper side, and to a plate which runs horizontally along the side of the ship, *above* the beams, but *under* the deck-planks. This plate is called a stringer, or deck-plate; it forms a most essential tie, and meets both the vertical and horizontal strains to which ships are liable. The plate is riveted to each deck beam, where it passes across it, and holes are cut in it to admit the stancheons of the bulwarks through it; tarred felt is usually laid on this plate before the timber water-ways and deck-planks are bolted to it. Much depends on the care taken in fitting the timber, and the number of the bolts used for fastening it.

In all plates employed as stringers in this direction, the joint should be made as nearly as possible of the same strength as the plates themselves. This is done by a broad strip, securely riveted under the plates at the point of junction.

Figs. 12, 13, exhibit a gunwale of nearly the same form as the last, but having the angle-iron outside, with the deck-plate also extending beyond the side, and riveted to the angle-iron. Through this plate, bolts are driven up, to secure the covering board. This

form allows of the bulwark stancheon being placed close to the ship's side, and adds to the width of the deck.

Fig. 14 is the same form of gunwale as fig. 10, but with the side plates carried up to form the bulwarks. In this case, every alternate angle-iron frame is passed through the deck-plate, and the angle-iron at the gunwale is made in short pieces between each frame, as it would be almost impossible to make the covering plate tight round the angle-iron ribs, the covering board is fitted closely up to them, and the work rendered water-tight by caulking. Iron bulwarks are found to answer best when made low, and surmounted by a topgallant bulwark of timber.

Plate IV., figs. 1, 2, show a form now frequently used for large ships; it will be observed that the outer plate is carried up about fifteen inches above the deck, the deck-plate is secured to it by angle-iron on its top side. At a distance of seven or eight inches from the outer plate is another, running parallel to it, and secured to the deck-plate by angle-iron; these should be caulked, and made quite water-tight, before the wood-work is attached. It will be seen that great strength is given to the upper sides by these means, and that a socket is formed for the reception of the foot of the bulwark stancheons without cutting a hole in the deck-plate, as in the former cases. In Plate XV. will be seen another plan, being a slight modification of the last. Instead of the usual covering board next the bulwark stancheons, a space is left, exposing the covering plate, and another bar of angle-iron is added, from which the planking starts. Between these two vertical plates are sometimes added iron brackets, to prevent them from being

forced open at the top side by an inward strain given to the bulwark stancheons.

The form shown in figs. 3, 4, gives still greater strength to the upper sides by adding a second stringer plate, and placing it on the under side of the beam, secured to the ship's side by short pieces of angle-iron. To the under side of this stringer, an angle-iron knee plate A may also be added. This form of gunwale most nearly corresponds with the cellular principle adopted in tubular bridges.

Fig. 5 is the last modification which it is necessary to represent. In this case, the side plates are carried up, as in fig. 14, Plate III., to form the bulwark, but it is supported by spurs, made of bar iron, and riveted to the deck-plate. When this plan is adopted, either from the difficulty of introducing the usual covering board, or from choice, the iron deck-plate is left bare, but has a bar of angle-iron riveted to its inner edge, forming an abutment to the deck plank. This form has advantages from its simplicity; but as a general rule, plates forming portions of a ship's deck, if left exposed, have been found objectionable. When the ship passes from a warm to a cold climate, the bilge water, or general moisture of the ship, rising in vapour to the deck, is immediately condensed by the iron plates, which are rapidly acted upon on the upper side by the cold atmosphere without. The water thus produced has fallen on the cargo, with the same injurious effect as from a leaky deck.

This objection applies with still greater force to decks formed entirely of iron, a few unsuccessful attempts at which have occasionally been made.

Lower Decks, Hold Beams, and Stringers.

The lower deck beams of an iron ship are similar to those of the main deck, the principal difference being that the stringers are not generally attached to the shell, but to the reverse angle-iron of the frames. After the beams have been secured to the ribs, the stringer plate is laid down, and attached by a bar of angle-iron on the upper side to the frames. See Plate IV., fig. 6. Latterly, however, in some cases the angle-iron has been cut into short lengths, placed between the frames, and riveted to the outside plates. In this case spaces have to be cut out of the stringer plate for every frame; notwithstanding this, however, the latter plan seems to have advantages, by making a firmer union between the stringer and the shell.

As a substitute for lower decks, and to increase the stowage of the ship, hold beams of great strength are made, and attached by stringers to the side of the vessel. These, being distant from each other, are made stronger than the other beams, and two of the most usual forms are shown in Plate IV., figs. 7, 8. The former is a box beam, made of plates and angle-iron the latter is formed of a plate, with four bars of angle-iron, riveted so as to form a double T.

Diagonal Ties.

The subject of diagonal ties has been much debated by men interested in iron ships. Many plans have been suggested and applied, while some patents have been taken out for them; but in the form in which they are

usually applied in large wooden ships, and where they are almost essential to sound work, they are of doubtful advantage for iron ships. They are used in wooden ships generally to counteract the vertical strains upon the sides, which, acting directly on the seams, have a tendency to loosen the whole vessel; but the outside plates of an iron ship are in the best possible position for resisting such strain, being themselves one great homogeneous mass, and no diagonal tie that can be added can give much additional security. If more strength is required in this direction, it should be given to the plates, this having the further advantage of insuring increased durability to the ship in the greater thickness of the iron. But diagonal ties have been used advantageously in iron ships, in a horizontal position, as a brace to the upper part of the ship, and are inserted between the planking and the beams, being riveted to the latter. These bars have been placed at intervals of eight or ten feet diagonally across the ship, and crossing each other in the centre, except where the hatches prevent it; they are then secured to the coamings, or such other objects as the case admits of. These trusses are represented on the general deck plan in Plate X., fig. 2. They form an efficient and excellent support to long ships.

Iron Stancheons.

Stanchèons for supporting the deck beams of both wooden and iron ships are almost universally adopted, and bear an important part in preserving the correct form of *the whole structure*. In iron ships, their *application is simple* and effective. They are gene-

rally applied to the alternate deck beams, and in large ships are made about three to four inches diameter. They consist of simple round bars, to which is welded at each end a small cross, to form the head and foot, having two holes in each, by which they are bolted to the beams or keelsons above and below. These are clearly shown in Plate XIV.

Mode of Plating.

The plating is the next subject for consideration, and in this, as in other portions of these descriptions, it is not here intended to point out the proportionate scantling required for different vessels, as this will be done in another place, but rather to confine it for the present to general terms, and to state dimensions so far only as is necessary to convey some idea of the usual methods adopted in iron ship-building.

Plates of all forms and dimensions have, at various times, been used by different builders, from 1-16th to an inch in thickness, according to the size and required strength of the vessel. These are not, however, the limits within which the plates must of necessity be made. It is generally acknowledged that the plates used for iron vessels were at first too light; but, as the subject came to be better understood, plates of greater strength were employed. It is, however, worthy of remark that many vessels, varying from ten to twenty years of age, are now at work and in good condition, after having undergone the severest service to which vessels can be exposed, and these vessels were originally much lighter than is now deemed sufficient. On this branch of the subject more diversity of opinion is manifested than on that of "framing," the object of

the latter being principally to preserve the form of, and to give stiffness to, the former. The impolicy of using light plates in the construction of a vessel is sufficiently obvious, for the additional weight given to the ship by increased thickness makes an immaterial difference in the draught of water, but materially increases the strength and durability of the ship. The scope which is afforded in iron vessels for increasing the strength of the framing is almost unlimited, and this by simple and evident means; but the question as to the best disposition and proportionate strength of the plates, involves so many difficult and nice inquiries, that experience alone can satisfactorily determine it.

There have been three methods in common use of applying the plates in the construction of iron ships. Two of these are shown in various forms in Plate VI., figs. 6 to 15; one of them is by bringing the edges of the plates together, and covering the joint by an internal lap or welt, and uniting them by two rows of rivets, fig. 8: the other is, by lapping the edges and uniting them by one row of rivets, fig. 6. The former corresponds with what is termed carvel build in wooden ships, and the latter clincher build.

Many attempts were made, in the first instance, to carry out the flush system for the horizontal, as well as for vertical seams, as in figs. 10, 11, 12; but the more simple plan prevailed for some years of lapping the plates for the horizontal seams, and making the vertical seams flush, figs. 13, 14, 15.

A modification of the clincher plan has latterly been introduced to the exclusion of every other, as affording great facilities in *plating*, and also producing sounder *work,—each alternate* strake of plates is laid flat to

the frame, and the intermediate strake is placed with both edges upon the neighbouring plates, as at fig. 5, Plate VII. In the original plan of lapped joints, a space was left, as at A, fig. 4, behind every plate, requiring a wedge of iron to fill up the space between it and the frame; but with the last-mentioned system, fig. 5, a space, B, is left only between the alternate plates, and that is not wedge-shaped, but parallel, requiring only a strip of plate or bar-iron to fill the space. The superiority of this plan will be apparent.

Ship-builders cannot be too strongly urged to avoid the mischievous system of putting mere washers where the rivets come, in those spaces between the frames and the plates, instead of filling up the whole space by a bar. The subject of some better means than are at present in use for fitting the ends of plates or the butt joints, should receive the most careful attention of ship-builders; it is usually done by the plater beating down the projecting parts of the edge with his hammer till he considers it sufficiently straight, and when well done a sound joint is made; but as the *degree* of accuracy thus attained is very much at the discretion of the workman, there is no certainty about it; and especially, as imperfect work is easily concealed, it requires great vigilance to give assurance that the plates are well fitted before a caulking-tool is applied.

May not machinery be here used to advantage, to give that accuracy which is seldom attained by other means? Much thought has by some parties been bestowed upon the subject, and in some cases the edges of plates have been planed, but not as yet successfully in the curved parts of iron-ships.

Another plan lately introduced by Mr. Lamb, of

Southampton, deserves notice, though only as yet applied to two small vessels. Every plate is laid close to the ribs, as in fig. 6, without liners of any kind; the strip for covering the seam is placed externally and riveted in the usual manner, as at C. I trust this system will soon be applied to a large vessel, as it seems to have important advantages in facilitating the construction of iron ships. It will be observed that the projecting edges are similar to those in fig. 5, and I think do not constitute an objection to the plan.

Plates united with flush horizontal seams will evidently sustain the greatest strain, arising from a force applied to or affecting their horizontal edges, for the weight is entirely removed from the rivets, and the supposed tendency to tear open those parts of the plates which are weakened by the rivet holes, will only apply to the vertical joints. With the lapped seams, on the contrary, nearly all the strain produced by a weight applied to the edge, or rather margin, of the plates, is thrown upon the rivets with an apparent tendency to cut or shear them off in the middle of their length, or, in other words, in the centre of the lap; excepting in so far as this strain is counteracted by the adhesion of the plates at the joint, or by the frames, which, at short distances apart, cross those joints.

When a ship labours in a heavy sea, the strains are momentarily varying in amount and direction; it is therefore impossible to establish any rule by which their effect may be counteracted, and the only safe course is to apply the maximum strength that experience has shown to be requisite, or of which the materials employed in building, are susceptible. The *power of an iron plate,* while it is kept perfectly

straight, to resist a strain or pressure applied to its edge, is very great; and as this power increases in proportion to the square of the depth, we can easily estimate the strength of a ship's side to resist vertical strains, when it is formed as it were, into one large plate. This, indeed, is so far beyond what can ever be required, that we can readily forego a portion of it, to obtain strength in another direction,—that is, to resist strains which tend to disturb the correct position of the plates. And although the strains arising from the vertical pressure on a ship's side very much exceed those caused by the inward pressure of the water, or by the ordinary concussions of hard bodies, it can easily be shown by calculation, that the strength of the plates in a vertical direction is proportionately much greater to resist strains given out in that direction, than their strength in a lateral direction to resist strains arising from inward pressure. From this reasoning, the lapped joint appears to be preferable to the flush joint, and has for a long time superseded the latter.

Single and Double Riveting.

As before stated, the vertical pressure exerted on the lapped joint has an apparent tendency to cut off the rivets in the centre of their length; and a very general impression prevails that, if a great strain were applied to the lapped edges of a number of plates, such would be the result. Experience, however, does not bear out this supposition, for it is well known to practical men that although rivets become loose, and the heads sometimes come off, through defective workmanship, yet the plates themselves generally give way first,

tearing in the parts weakened by the holes formed to receive the rivets. As, however, the space between each hole, in single riveting, exceeds the diameter of the hole, more than *half* the original strength of the margins of the plates overlapped remains after the holes are punched; and where a double row of rivets is adopted, more than *two-thirds* of the original strength of each plate is left.

The subject of double and single riveting the joints of the plates, is a much vexed one amongst iron ship-builders, and requires to be examined with great caution. Single riveting with lapped joints requires one row of rivets, but in the flush joint it requires two rows, see figs. 6, 8. Double riveting requires two rows, for the lapped joint, and four for the flush joint as at figs 7, 9. To determine the exact form and size of the rivets, and the distance from each other best suited to give the greatest strength to an iron ship, we must consider every requirement of the case, involving as it does, an inquiry into the nature of the strains to which ships are exposed. The principal of these evidently correspond with those experienced by a common girder, only that in the ship the action changes with the form or position of the waves on which she rests. When the wave is highest at each end, and the vessel as it were is resting on two waves, it is evident that the bottom receives the tensile strain, and the upper part is compressed; but when the wave is highest in the centre, or the vessel is principally borne only on one wave, the top-sides receive the tensile strain, and the bottom becomes compressed.

These strains are of a simple character and the effect on the joints is easily seen. The tendency is

alternately to tear open the vertical joints of the top and bottom sides, while the strain is directly at right angles to the horizontal seams. The length of the vertical seams, however, bears but a small proportion to that of the horizontal seams, and would be proportionably weak were it not that the former are not in one line, but are so crossed by the shifting of the butts, that their strength is preserved; they are however still inferior in strength to the horizontal seams.

The second class of strains which operate upon a ship, namely, the external action of the waves on the sides, which causes so much twisting and rolling, acts also unfavourably to the vertical or butt joints. It is therefore a wise decision in Lloyd's regulations for iron ships that all vertical seams shall be double riveted, leaving it to the choice of the builder in small vessels as to the horizontal seams.

Rivets.

Two works of a practical character which have been published during the last few years, contain valuable experiments on the subject of rivets and riveting. One by Mr. Fairbairn of Manchester, called "Useful Information for Engineers." In this is repeated an account of experiments, quoted in the first edition of this book, with important additions of later date.

The other work is by Mr. Edwin Clarke, resident engineer of the Britannia Bridge, containing amongst other valuable information, some elaborate experiments on rivets as used in uniting iron plates. It would occupy too much space to follow these gentlemen

through their experiments, but I will endeavour to cull from them a few facts and arguments that may be useful.

Mr. Clarke explains, that a rivet uniting *two* plates is in the condition of the pin that unites the two blades of scissors, and where a rivet secures *three* plates, it is in the condition of the pin on which the blade revolves in the handle of a pocket knife. In the former case the tendency is to shear the rivet in one place, and in the latter to shear it in two places, when a strain is caused which tends to separate the plates by tension. In ascertaining the force necessary to shear them, two simple laws were developed.

First, that the ultimate resistance to shearing is proportional to the sectional area of a bar torn asunder by direct tension; for instance, if it would require about twenty-four tons pressure to shear a rivet having one square inch of sectional area, it would require forty-eight tons to shear a rivet having two square inches.

Secondly, the ultimate resistance of any bar to a shearing strain, is nearly the same as the ultimate resistance of the same bar to a direct longitudinal tensile strain; that is, if twenty-four tons is required to shear a rivet having a section of a square inch, so is twenty-four tons or nearly so, the average breaking weight of a bar of the same size when acting by tension. He gives the mean of four experiments at 24·15 tons per square inch for single shearing and rather less for double shearing.

The experiments to ascertain the value of friction by the cooling or contraction of red hot rivets, have much interest. Mr. Clarke shows that if a rivet were closed at a temperature of 900 degrees, it would exert

a power in cooling much exceeding its own strength, and it must therefore become permanently elongated, and maintain a constant pressure on the plates at the head equal to the full strength of the bar, or about twenty-four tons, and the friction of the plates thus closed would have to be overcome before the rivet came into action as a mere pin.

It is only by machine riveting that the temperature of 900 degrees could be maintained till the rivet is formed.

Some simple experiments were then tried, to ascertain the amount of friction obtained by this effect in cooling. Three plates were brought together, each outside plate had a circular hole in which the rivet fitted exactly, but in the centre one the hole was oval or 2½ inches long for a ⅞ rivet, and the rivet was not allowed to touch either end of this hole; a strain was then put on the centre plate till it began to slide, which it did abruptly, several trials were made, and the least result was a friction equal to 4½ tons with ⅞ rivet, and this was greater than is supported by any of the rivets in the Britannia tubes, and Mr. Clarke supposes that the bridges would not deflect more than they do at present, even if the holes were larger than the rivets, so as not to come in contact any where except at the heads. This gives an immense reserve of strength, as the shearing strain is four or five times greater than the strain necessary to overcome the friction.

The inference thus drawn with reference to the bridge, is supported by the consideration that the actual deflection of the tubes is the same as that indicated by theory, for a tube formed of one welded piece of iron without joints.

We may perhaps safely continue the same reasoning and apply it to iron vessels, for although we cannot possibly estimate the strain to which a ship is exposed when afloat, I do not suppose that it is ever equal in proportion to its strength to the strain on the Britannia Bridge.

Mr. Clarke further supposes that by judicious riveting the friction may in many cases be nearly sufficient to counter-balance the weakening of the plates from the punching of the holes.

Mr. Fairbairn does not appear to give a result so favourable to the rivet as Mr. Clarke does, but he claims for machine riveting a superiority of five to four over hand riveting; he also gives the results of a variety of experiments of the power to resist tension in the riveted joints of plates, from which he came to the following conclusions:—

Taking the strength of plates at	100
Double riveted plates . . .	70
Single ditto	56

But even these results must be subject to modification, as laying aside the consideration of the strength gained by friction, the power of a joint to resist a tensile strain must depend to some extent upon the closeness of the rivets to each other, or in other words, to the number of rivets of a given size, and in any given length of joint. The average of several experiments made by Mr. Fairbairn gives 22·519 tons per square inch when the plates are torn in the direction of the fibre by the power being exerted perpendicular to it, and *23·037 tons when* torn in the other direction, *or across the fibre.*

Mr. Edwin Clarke, however, gives somewhat different results. He assumes that 24 tons per square inch may be taken as the ultimate tensile strength of a bar of the best rivet iron, while the ordinary plates sustained only 20 tons when applied in the direction of the fibre, or about 16½ tons when applied at right angles to the fibre.

Amongst the experiments by Mr. Barlow, of Woolwich, as to the relative power of pine and wrought iron to resist tension, we find that the latter is as 4·16 to 1 against the former; and that the power to resist compression or crushing is, in pine as 1 to 13 in favour of iron. And Mr. Hodgkinson says that timber, when wet, is crushed with half the weight which it will sustain when dry.

Mr. Fairbairn's experiments on the relative power of iron plates and timber planking to resist fracture from a bluntly pointed body pressed upon it, corresponding to the effect produced when the vessel rests, in taking the ground, on a round stone, or other similar hard bodies are interesting.

A plate was stretched firmly on a frame having an opening of 12 inches square, a bolt terminating in a hemisphere of 3 inches diameter was then pressed perpendicularly on the centre of the plate.

In the first experiments the plates were one-fourth of an inch thick, and were indented about a quarter of an inch with 9,700 lbs. and cracked through with a mean pressure of 16,779 lbs. On the experiments being repeated with plates one-half inch thick, they bore a mean pressure of 37,723 lbs., or little more than *double the former*, or nearly in proportion to their *thickness.*

With experiments on timber, conducted nearly in the same manner, the ultimate strength of an oak plank $1\frac{1}{2}$ inch thick, was 4,406 lbs., and of a plank 3 inches thick, 17,933 lbs, or as the square of the thickness.

The inquiry is frequently made, whether there is not great danger, should the heads fly off, of the rivets falling out and leaving a hole for the admission of the water. The heads do occasionally break off while the workmen are in the act of riveting, and when the holes are badly formed; but when the iron is good, this seldom occurs. Should, however, the head of a rivet break off when the vessel is afloat, it by no means follows that the rivet itself would fall out. On the contrary, when originally secured in a workman-like manner, the piece remains so firm in the hole that it requires the application of a steel drift and a heavy sledge to drive it out. This circumstance is easily accounted for by an examination of the transverse section of the rivets, Plate VI., fig. 5, as they fill the holes in the two plates; the holes being seldom exactly fair with each other, the rivets swell out and accommodate themselves to the precise shape of the holes, like melted lead run into a mould. The annexed drawing, taken from some rivets, which were cut through the centre in the planing machine, explains this peculiarity. While it is admitted that the most judicious use of the materials of which a ship is composed is of great importance, I am inclined to lay even greater stress on the necessity for good workmanship; the former can be regulated by the terms of a specification, the latter only by skill and care; and although attention to the latter is in the end cheaper both to builder and owner than slovenly

work, yet I regret to say, that bad workmanship has been so frequent as materially to retard the progress of the system. The plating and the riveting are the two points that need our closest attention, as defects in these will certainly result in having a leaky ship.

The great art in building consists in having no points where a movement can begin, for it must be recollected that the weakest point is the measure of strength. The size, form, and number of the rivets are also of great importance in considering this branch of our subject, and the best rules for these are perhaps to be found in Lloyd's Regulations, given at the end of this book.

I will first describe a rivet, and the mode of applying it.

Plate VI., fig. 1, exhibits the form of a rivet before being used; it is made from a bar of the best iron that can be procured, and is moulded to the required shape in machines, patented by different makers. There are three modes of riveting. First, by the use of hammers, striking directly on the rivet. The head, in this case, is generally of a conical form, as in Plate VI., fig. 2, or flush with the plate, as in fig. 4. Secondly, by the intervention of a die, struck by a heavy hammer, as at fig. 3, called snap-head riveting. And thirdly, by the application of machinery. A riveting press, invented by Messrs. Garforth, is represented in Plate XVI., and will be afterwards explained.

This can be used only to a limited extent in ship-building, and no feasible plan has yet been suggested for superseding the old method of hand-riveting in all work that has to be executed in the vessel on the slip. In ship-building it is necessary that the outer end of

the rivet should be flush with the plate, so that the surface of the ship may be smooth, and for this purpose the rivet hole is countersunk, or made conical from the outside.

The operation of riveting is performed by three men and a boy, viz:—two riveters, one holder up, and a rivet boy. The tools used by them are shown in Plate XVII., figs. 3 to 10. The rivet being carried in the tongs, fig. 3, by the boy to the holder-up, is taken up by him in the shorter tongs, fig. 4, and inserted into the hole from the inside; he then presses against it with the hammer, fig. 8, or with a tool called a dolly, figs. 9, 10, the end being indented to receive the head of the rivet.

The riveters then commence the operation of riveting, by a few rapid and hard blows with proper hammers, fig. 5, weighing from 2½ to 3lbs. Should the rivet rather more than fill the hole, the portion projecting may be cut off by a chisel. The operation is then changed—the man on the inside, with a heavy hammer, fig. 7, strikes the head a few heavy blows, while those outside hold up in their turn; he also strikes the plates round about the rivet, so that all is closed firmly up; lastly, the men on the outside, having first given a few blows with the hammer, fig. 6, complete the work with the light hammers.

The more rapidly this work is performed the better; the blows should be hard, and given while the rivet is hot. Should any delay take place, and the rivet become cool, so as to lose its bright red glow before the first blow is struck, it should be rejected. Many object to riveting being performed by piece-work, but if it is closely inspected and not slighted, I am inclined to think that it gives rapidity to the blows, the rivets

consequently have less time to cool. The system of forming snap-heads, as before described, scarcely applies to ship-building, and is seldom used, as there are only a few non-essential points where it is applicable.

The number of rivets driven by a set of riveters in a day's work of ten hours is about 100, but if employed by piece-work, this number will be increased to about 140.

BULKHEADS.

Iron vessels admit of the very easy introduction of water-tight bulkheads. These are formed by plates, riveted to the ribs or frames, both on the sides and bottom, each bulkhead making a complete transverse section of the vessel, and the whole being so secured as to prevent water passing from one side to the other. Several of these being introduced, divide the vessel into water-tight compartments.

The bulkheads affording the greatest protection are those placed a few feet respectively from the stem and stern; the forward one checking the water that would enter through a damaged stem, and the after one averting the danger of any accident that might arise to the stern-post, or rudder-braces, or to the tube of the shafts of screw vessels. The water received into these small compartments would very slightly impede the way of the ship by throwing her out of trim, as the quantity they would contain would be comparatively trifling. The bulkheads more a-midships, have generally been so distant from each other, that they have not been very serviceable in keeping the ship afloat when a hole has been made in the centre compartments. They, however, assist in giving additional

strength, afford safety in the event of fire, and prevent it spreading beyond the compartment in which it commenced. An ordinary leak, too, in one of them, may be overcome, and no damage arise to the cargo or stores in those adjoining. These are advantages which it would be difficult to attain so effectually in a timber-built vessel.

But more attention has lately been given to the subject of bulkheads, as the advantages to be derived from them are becoming more evident, both in giving strength to the vessel, and in saving life and property. In a steam vessel I had designed and where the bulkheads had received much attention, their utility was put to a severe trial. In a gale of wind a pipe belonging to the engines and connected with the sea burst, and the water overpowering the men, soon filled the engine-room. Being deeply laden, the vessel became unmanageable, and not being able to make the harbour she was bound for, came to an anchor in this state and rode out the gale. On freeing her from water, not a drop had penetrated to either hold, and the ship was quite uninjured.

Water-tight bulkheads have for ages been in use in China, but have only been generally introduced into this country since iron ships have been used; they are now employed in all iron vessels, and their adoption has become a law and is enforced under the regulations of the Board of Trade; in small vessels they can only be used transversely, but in larger ones they may be applied longitudinally, and are so employed in the *Leviathan* now building at Millwall, on the Thames.

The modes of making and securing bulkheads, have

been the subject of much discussion, and drawings are given of two of the best plans now in use. Some builders have merely secured the bulkheads to the ordinary frames of the ship, but this is not only useless as a protection to the ship, but is absolutely unsafe, the strain given to the bulkhead being received by the few rivets which are usually applied to the frames, these break or become loose, and the ship is thereby rendered leaky.

It is undesirable to increase the number of rivets in the frame to any great extent in a continued line across the ship, as the plates are by this much weakened, and the shell rendered liable to tear in that place. The loss of some vessels has been attributed, and I fear with justice, to this cause.

Plate VII., figs. 1, 2, represent one of the plans of forming and fastening bulkheads, and is that which I prefer and generally adopt. Fig. 1, is the elevation, and 2, the plan, both being in section; the frame A, is made of angle iron, about 6 inches by 3 inches, having the longer arm next the outer plates, the rivets are in two rows or zigzag, and thus a large number are introduced without the holes in the shell being so near to each other as to weaken the plates. In large ships the addition of brackets made of angle iron, and triangular plates are recommended placed alternately on each side of the bulkheads. These are also stiffened by angle iron, or half-round bars, riveted to them at certain intervals in a vertical direction; where there are lower decks, these should also be well tied to the bulkheads by horizontal bars of angle iron, riveted to them, receiving also the ends of the planks.

Fig. 3, shows the plan of securing the bulkheads to

the ship's side, by two bars of angle iron marked B. and to this plan also are applied brackets as above described.

Valves worked by rods from the upper decks, are placed at the bottom of the bulkheads to be opened and shut at pleasure.

The regulations required to be observed, both by the Board of Trade, and also by the Lloyd's Committee, will be alluded to hereafter, together with some considerations as to the utility of bulkheads as bearing a part in the general strength of an iron ship.

Iron Masts.

The parts of iron ships which have usually been built of that material, have been thus far enumerated; but it has occasionally been extended to other portions. The masts, boats, deck houses, companions, and hatch coamings have been frequently built of iron; but it is only necessary to describe the first of these, iron masts being the most important deviation of this description. An iron mast was placed in one of the City of Dublin Company's steam vessels about twenty-five years ago, and remained there for several years. Great confidence was placed in it for lifting the heaviest weights; it acted, also, as a ventilator for the cabins. Within the last few years iron lower masts have been made for large sailing ships and steamers, and possess advantages that deserve notice. Plate VIII.—figs. 1, 2, 3, show the ordinary main fore and mizen masts of a ship; and figs. 4 to 9 are plans showing the elevation, with longitudinal and cross sections of the main mast. It is made of plates bent so as to take

the form of a timber mast; these plates are jointed by internal strips, as in the butt joints of the hull. An internal cross flanch made of plates and angle iron, and sometimes of T iron, as in fig. 5 is also added. In some cases the plates are lapped, as in fig. 8.

The head and foot are formed externally like wooden masts, and the cross-trees are also of iron. The plates used vary from $\frac{3}{8}$ths of an inch to $\frac{5}{8}$ths in thickness. They are lighter and stronger than timber masts, and when compared with the built mast of large vessels are rather less expensive. For vessels of the same tonnage the difference of weight is nearly two to three in favour of iron; for instance, the weight of the three lower masts and bowsprit being accurately calculated, the wood masts with the hoops and iron work weighed 27 tons 10 cwt., but the iron masts weighed only 18 tons 10 cwt.*

Timber masts of large dimensions are difficult to procure, and by the adoption of iron much inconvenience is avoided. In a well-painted iron mast there is no danger to be apprehended from decay, corresponding to that which so often invades the timber mast; and which frequently, by its sudden failure in bad weather, causes the loss of the ship.

PROCESS OF BUILDING AN IRON SHIP.

It will readily be supposed that hitherto the opinions and practice of builders have been found to differ in different places; but as the operations in the process

* I am confirmed in this estimate, as well as in the weight of the iron required in the construction of different vessels, by Mr. John Vernon, whose calculations are made with much care, and may be depended upon.

f iron ship-building are simple, so the mode of contruction, as well as the plans adopted, are fast ıssimilating, and greater uniformity is to be observed ın this science than in almost any other of a practical nature. I have seen many building-yards both in England and on the Continent; and everywhere the same machinery is used and the same plans are followed. There are many points so self-evident, so simple, and withal so efficient, that there is little room for any material differences to arise; but to many who cannot witness the operations throughout the whole process, a slight sketch of them may be interesting. In giving this, I shall be naturally led to describe that which commends itself most to my own judgment and has fallen most within the scope of my own practice.

The work first begins in the drawing room, where the draftsman lays out the lines of the vessel to a $\frac{1}{4}$ or $\frac{3}{8}$ths of an inch scale; from this it is usual to prepare a model, to be constructed as follows:—Thin slabs of wood, equal in thickness to the horizontal or water lines of the drawing, are carefully prepared, and to these are transferred the half-breadth lines of the vessel. Each board is cut to the shape of the water line thus drawn upon it; and the whole is either bolted or screwed together, and carefully pared down by a spokeshave. By this half model the eye is assisted tc form a more correct judgment of the intended ship and improvements may be made by a further use of th modeller's tools. Some builders omit this process, bı no one who can appreciate the extreme quickness the practised eye to detect errors in form, will despi this simple method.

After the model has been decided upon, revised drawings should be made from it; and here I would strongly urge that more care than is usual should be bestowed. The details can be much better considered in a quiet drawing office than in noisy workshops; time and money will both be spared, by giving more of the former to making complete drawings.

The builder now prepares what is called a block model, on a larger scale; upon the surface of which he draws every plate and every frame, being regulated in this by the specification which has been given him. Short extracts from approved specifications will be inserted at the end of this work. A mark is then put to every frame and plate, and a list is made of the size and thickness of each. From this list the order to the manufacturer of the iron is made out; the plates and sometimes the frames are thus prepared at the Iron Works to the exact size required, and much trouble and waste are spared in this department. While this last process is going forward, the "laying down" of the vessel is in progress.

The usual practice has been to draw the vessel on the floor of the mould-loft to the natural size, and from this to make the moulds for the workmen. This plan, however, has disadvantages, especially with extremely long vessels, where few lofts are long enough to admit of the whole being drawn at one time, and great difficulty has been found in preserving the lines with correct curves throughout. To obviate this, I recommend the substitution of drawings on paper to a large scale. The whole can then be viewed at one time, and the preparation for the workmen is accurately and effectually carried out by the next operation. A board

rather larger than the transverse section of the ship is now made; and to this are transferred all the sectional lines of the ship, drawn to the natural size; on one half, those of the fore body, and on the other, those of the after body. To assist this description, I refer the reader to Plate IX., fig. 4, where these lines are represented on this large board. In the drawing here given, however, to avoid confusion in so small a scale, only one frame in four is traced.

The sectional lines are, in fact, the frames, and each of these has a mark; one end of the ship is marked with letters, and the other with figures. The diagonal lines are marked R L, or ribbon lines. It must also be observed, that the angle iron of each frame, as it approaches the ends, requires some alteration in the angle, so that one arm may be at right angles to the keel, and the other arm be flat to the ship's side. This may be noticed in Plate X., fig. 3.

When all is drawn out correctly, a thin wooden mould is made to each frame; and at the points where the ribbon lines cross them, the bevel required for the frame is described on another board, sometimes called the bevel board (see fig. 5, Plate IX.), which is generally made of a convenient form to be used by the men, say 4 feet long and 6 inches wide; the letters and figures show to which part of each frame the angles apply; thus all the angles at the ribbon lines in frame H, are shown by the respective lines also marked H on the bevel board, fig. 5.

The men thus prepared proceed with the next operation. Fig. 6 represents some massive plates, called levelling blocks, weighing several tons, each about 10 feet by 3 feet, having a great number of holes cast in

them. On these plates the form of the rib to be bent is marked from the wooden mould, and pins are placed in the holes, as shown by the black marks. Long bars of angle iron previously heated are brought by several men to these levelling blocks; and there by dint of hammers, wooden mawls, tongs, and handspikes, the bar is bent and secured by the pins, as shown in the drawing; and before it has time to cool, some men are opening out the angle iron at the points marked R L, 1, &c., to correspond with the angles shown on the bevel board, fig. 5. The half-frame of a ship is thus fashioned to the proper form in less time than it has required to describe the process; and it is now ready to be taken to the punching press to have the proper holes made in each arm.

While all this is going on, the blocks are being laid in the ship-yard in the usual manner, and the keel, stem, and stern posts, as shown in the detail and general drawings, are being forged and drilled. These are set up, and the first strake of plates, called the garboard strake, is bent and secured to the keel. The frames are then set up in their places, and are kept in their proper position by shores and ribbon pieces, or pieces of narrow planks running from end to end of the ship in the position marked R L on fig. 4, plate 9, and to which the frames are bolted.

The operation of plating then proceeds, first, by fitting those plates which lie flat to the frames, and attaching them by temporary bolts or cotter pins; see Plate XVII., figs. 20, 21. These plates are put on one by one, and the skill of the plater is shown in preserving the even curves of the ship, and by making the plates fit well at the ends to the neighbouring plates. The

necessity of having the butt joints well fitted cannot be too strongly insisted upon. The usual plan is for the plater to strike the edge of the plate with a hammer till he has flattened down all the prominent parts, and then, when the butts are brought together, a tolerably close joint may be made; but in many cases this is not done, and the defective seam is too easily concealed by caulking to be at all times detected. It is much to be desired that machinery may in time be applied to perform this operation, as the present system is far from satisfactory. Those plates which have to be much bent, are generally put into the plate-bending machine hereafter described; and by this and other means they are brought into the required form. All the holes required for the rivets in these plates may now be punched.

The thickness pieces that are to fill up the spaces between the frames and the intermediate strakes, are then made ready, and the plates themselves are bent to their position; but the holes in these must be marked to suit the position of the holes in the first or lower strakes. This is generally done by inserting into the holes already made a round plug of wood, previously dipped in paste made of whitening. The exact position of each hole is thus imprinted on the outer plate, and if carefully punched to these marks, the holes in each plate will come fair with the others, the rivets will be inserted without difficulty, and the whole will be sound and tight.

The work now becomes general all over the vessel; the riveting is in progress, the beams previously made and bent are put up, the flooring plates are put in, the bulkheads, stringer plates, keelsons, and crutches

are added in due succession; thus the full and perfect form of the ship is gradually developed, and exhibits one of the most interesting and useful productions of man's labour.

The process of riveting has before been described, but another is to be added before the seams of the ship are considered sound; this is, what is termed, caulking, but is a very different operation from caulking in a wooden ship. It is performed by two men, one holding a chisel or caulking tool, and the other striking it with a hammer, making a slight indentation along the seam, as shown in Plate XXI., fig. 2, at the point *a*. It will be seen that the effect of this must be to force the edge of this plate hard against the other at *b*, and thus fill up any slight crevice between the plates which the rivets have failed to close. The tools used in caulking are represented in Plate XVII., figs. 11, 12, 15, and 16; but others, with a flat point used for the vertical flush seams, are shown at figs. 13 and 14.

It is not necessary to describe more fully than I have previously done, the wood work of an iron ship, as this does not differ materially from similar work in wooden ships; but it cannot be too often impressed upon iron ship-builders, that one very just complaint against iron ships has arisen from the imperfect manner in which the two materials have been combined, causing a leakage which it is difficult to stop.

Description of Vessels as shown in the Plates.

I have found much difficulty in deciding on the course to be pursued when considering the modes by which the combinations of the various parts already

described could be best illustrated, so as to convey to the general reader and to the practical man, a clear idea of the structure of an iron ship as a whole. One apparently obvious way was to select examples from the various eminent builders, and illustrate them by a series of drawings, but this would require a large number of elaborate plates, bearing, in the leading features, a great resemblance to each other; and as each builder is required, to some extent, to build his vessels to suit the views of their future owners, or to meet the peculiar service for which they are intended, the idea of any distinctive character attaching to any particular builder must be lost sight of. In a science also that is essentially progressive, every builder must confess to the necessity of continual change in the designs as well as details, and no one can say that, before another year has passed away, he will not see occasion to make some improvement in his former practice.

It is not the object of this work to give designs of ships; this occupies a much wider and more difficult field than I have undertaken. I can only take the few simple forms in which iron is manufactured, and show how these are applied and combined, so as to form that wonderful thing—a ship. The principal details, as adopted by all makers, have already been minutely described, and I now proceed to show the combination of them in one body; after which it is proposed to add extracts from the specifications of several well-known vessels, together with the latest Regulations published by Lloyd's Committees for the registration of iron ships. These, taken together, will embrace the combined views of all the leading ship-builders in this

country, and convey all the information that can be obtained to the present time.

The drawings, about to be described, represent a screw steamer, as being the kind of vessel to which iron is most generally applied, but it will readily be seen that the details and mode of construction will be the same in paddle-wheel steamers and in sailing vessels as in screw steamers, except in those parts where the introduction of the machinery requires some deviations to be made. The larger vessel shown in the drawings is 300 feet long, 43 feet beam, 28½ feet deep from base line to the under side of gunwale amidships; and is equal to 2696$\frac{7}{10}$ tons, builders' measurement.

The smaller sections, figs. 2, 3, Plate XI., represent vessels of 919 tons and 272 tons respectively, and merely point to the distinction of smaller vessels with and without lower decks.

Plates X. to XIV. represent the general plans of a vessel of the first class.

Plate X. contains the sectional elevation, with the half-breadth plans of the main and lower decks, and at the orlop beams, the forecastle, poop, main, and lower decks, with the various bulkheads and lower hold beams.—See fig. 1. The plan of the main deck (fig. 2) represents the system of deck trussing before described, as applied to large ships. They are riveted to the deck stringers and to the upper side of the beams, over which they pass. These stays are light and effective fastenings to a long ship, but cause some additional labour in laying the decks, as the under side of the planks must be grooved where they cross them. Fig. 3 is the lower deck, and on this is shown the fore and aft tie marked, B, riveted to the upper side of the deck beams, and to

the covering plates. Fig 4 is a horizontal half-breadth plan at the height of orlop beams.

Plate XII. contains two views of the fore body of an iron ship, of the same dimensions as in Plate X. Fig. 1 is a longitudinal section. Fig 2 is a transverse section at *a*, *b*, looking towards the stem. The forecastle deck is marked A., and this, together with the sides above the main deck, is more lightly framed than the parts lower down. The deck beams may be made of common angle iron, and the reverse angle iron is not usually added to the side frames. This deck is sometimes carried the entire length of the ship, and forms a spar deck.

B and C are the main and lower decks, the details of which are also given in the former plates, and the dimensions of which will be seen in the specifications at the end of this work. Below these a tier of fastenings is represented, and marked D. This is the position of the orlop deck, but beams and stringers only are shown in this drawing, as usually applied to cargo vessels in the merchant service. One of the lower deck beams is seen abaft the bulkhead, these are continued at intervals of about six feet throughout the ship, and are important fastenings that cannot safely be dispensed with in deep ships, and are required by Lloyd's Regulations for ships above a certain depth. All these beams are connected to the ship by stringers, such as before have been described. In the drawings the beams and plates, where shown in section, are marked in strong black lines.

Similar fastenings are introduced still lower down, as shown at E, and consist of a stringer on the ship's side, running throughout, and again seen in Plate XIV.,

in the bilge. Forward of the bulkhead, a few light beams or stretchers are also introduced.

The termination of the main keelson, where it is attached to the bulkhead, is shown at F, and under it are seen the floors in section. In consequence of the fineness of the lines at this place, the keelson is curved upwards, and the floors are deepened.

If the reader will now look at the upper part of the vessel, he will see a partial bulkhead under the forecastle deck, marked G, used for the double purpose of supporting the end of the tube for the bowsprit, and of strengthening the sides; this has a man-hole in it, to enable men to pass beyond it for cleaning and painting. At the fore part of the small compartment thus formed is the apron-piece, H, a strong plate extending from the deck to the stem at *h*, where it is bolted and made water-tight. From this downwards, as far as the bulkhead, several plates marked I, are shown in section in fig. 1, and as flat plates in fig. 2. These are termed crutches, and are used where the space becomes too narrow for beams and stringers, and like them, are essential to the support of the fine ends of iron ships, both stem and stern. Timber-built ships are made nearly solid at these points, but in many iron ships, where the long concave lines of the bow render the outside plates unable to withstand the external pressure of the water, these fastenings have been omitted. This has occasioned defects, for as the vessel plunges into a heavy sea, the increased pressure causes the plates to yield inwards, and gives rise to a motion in the sides that soon loosens the rivets, and opens the seams at the butts. This has led to unnecessary weight being given to the frames and plates in these

places, while experience has shown that a small amount of iron, used as above described, has entirely overcome the difficulty.

The cutwater, where such appendages are used, is formed entirely of iron, and should be made water-tight, by a plate marked K, on the upper side, extending down the seat of the figure-head to the stem post.

The upright plate at M, is the forward bulkhead, extending from the keel to the main deck. The bulkheads have before been described, and the usual position of them, as applied to steam vessels, is shown in fig. 1, Plate X.

I may again draw attention to fig. 1, Plate XI., where some features are introduced that deserve notice, as required for steam vessels. The plates marked A, represent the section of the coal bunker, running fore and aft the ship, and extending from the main deck to the floors, and supported from the sides by the stays, B. It will readily be seen that great strength is given to the vessel by these fastenings, in a part where the usual supports derived from deck beams and stancheons, are broken into by the boilers and machinery. It is not possible to give any detailed plan for this description of fastenings, as their form must depend on the arrangement of the boilers and machinery—a subject that comes more immediately within the province of the engine maker—and therefore I can do no more than strongly recommend the greatest attention to the skilful application of these means to add to the stability of steam vessels. The large box beam, marked C, is also a useful addition in the engine compartment.

Plate XIII. contains two views of the after body of

a ship, similar to that shown in Plate XII. Fig. 1 is the longitudinal section, and fig. 2 the transverse section at *a*, *b*, looking towards the stern. The poop deck, corresponding with the forecastle deck in Plate XII., is marked A; B is the main deck; C the lower deck; D the line of the orlop beams; to all of which the remarks made upon corresponding parts in the fore body will apply. The plate E corresponds with the stringers bearing the same mark in Plate XII., but is lost in the foreside of the bulkhead, F, by forming the bottom of the screw trunk S, hereafter described. F is the after bulkhead, leading up to the lower deck, and formed as before stated in the detail drawings; G is a partial bulkhead, with a man-hole, *g*, and is made to support the cast iron tube and gland of the screw shaft. A second plate is sometimes added to stiffen it, and to make a better support for the bolts of the gland.

The plates shown in section at the parts marked H, are the floorings and crutches employed, as in the fore body, to support the outer shell, and preserve the form of the vessel in the flat or hollow portions of the run of the ship, and to counteract the tendency of the screw to strain the seams at this point. Some of these crutches, as well as the bulkheads and stern post, are fitted accurately to the tube. This is done by turning the tube itself externally, and boring the holes that are to receive it at the points marked *h*.

This operation should never be performed until all the riveting is finished, to avoid any derangement of the strict accuracy required in the shaft.

The plates marked I are similar crutches, and correspond with the transom pieces and stern frames of a wooden ship.

The large framework marked K, extending from the upper deck down to the keel, and round the screw port, some distance into the keel, is a massive piece of work, made of wrought iron; this, as well as the rudder, is also seen in section at the points *c, d, e, f*. Projections are welded to the outer stern post, in which the rudder-pins work, and there is one at the keel, on which the rudder rests.

The stern frame of a sailing ship would be of the same form, with the exception of that part which forms the screw post, or inner stern post. This frame in small vessels is generally made in one piece, but in large vessels, on account of its great weight, is generally scarphed at the points marked L. Scarphs, however, are best avoided, where practicable. The parts of the stern post and keel, where the plates are to be attached, are bored with numerous holes. The inner stern post has a large boss forged on it, into which the tube for the screw shaft is secured. Round this boss the plates are bent, and this necessary swell is continued, as at R, till it is lost in the increased width of the ship, between ten or twenty feet from the stem.

The rudder, M, is framed with wrought-iron, the stock is round as in section *c d*, and the upper part should be turned so that it may work in a gland or stuffing-box, having a little soft packing by which the noise of the rudder jarring and striking in heavy weather is prevented; but at N it changes its form to a rectangular shape, as at section *e f*. The after part, which branches off at N, is a lighter bar, and is connected lower down to the rudder-stock by two cross-bars, O. The frame being thus prepared, is plated on both sides with light plates.

The tube marked P is usually of cast-iron, and is made to receive the screw-shaft; it is inserted with great care, as before described, into the after-part of the ship, and a large nut is placed externally to keep it firmly in its place. Various plans are adopted for the bearings of the shaft in this tube. Some line it with brass, some with block-tin, some with hard wood, while some simply bore out the iron itself, and prefer it to the other means here named. This, however, is more in the province of the engine maker, and has no particular reference to iron ships, as timber-built vessels must have the same appliances. The gland marked Q, is used for packing the shaft with hemp, to keep the water out of the vessel, and requires the constant attention of the engineers while at sea; means are, therefore, provided for the men to get to it either from the deck through hatches left for the purpose, as at X, or direct from the engine-room through the *screw alley*. This is also described in fig. 3.

Where convenient, this passage is made to extend from the engine compartment to the bulkhead F; and in large vessels, admits of a free passage for the engineers to pass through it, to attend to the bearings of the shaft while the engines are at work.

The shaft V, works in a plumber-block, resting on a square wrought-iron upright U, and this is covered by the casing T, to prevent the cargo pressing on the shaft, and having a water-tight bottom at W on which the men can walk. It is evident that if the construction of this is well attended to, the engineers can pursue their important duty, even if the ship were on fire, or with a great depth of water in the after hold.

I now proceed to describe the midship portion of the vessel, as shown in Plate XIV.

Plate XIV. contains a single drawing of the midship view of a large vessel, and corresponds with those represented in Plates X. to XIII. The reader, to understand this drawing, must imagine the ship cut transversely and longitudinally, and that he is standing opposite the angle where these lines bisect each other; he will thus see on his left the section of the outside plates, stringers, bilge-pieces, keel and keelson; and on the right, sections of the beams, stancheons, and floors, together with longitudinal sections of the keel and keelson. The wood work of the decks and bulwarks only is shown, that the view of the iron work may not be intercepted. A represents the timber bulwarks secured to the iron work, as previously shown in Plate IV., fig. 1; B, the main deck; C, the lower deck; D, the orlop beams; E, the bilge stringer, all represented in detail in Plate IV.; F is a longitudinal section of a box keelson; G, the floorings, cut through the hole *g*, usually provided in ships with solid keels for the passage of bilge water; H, is the keel, and I the sister keelson, acting also as wash plates between the floors. The whole is bound together down the centre of the vessel by the iron stancheons, K, which are placed under every second deck beam.

MANUFACTURED IRON USED FOR FRAMES, BEAMS, ETC.

It was many years after the introduction of the system of forming bars and plates by rolling, that similar means were used to produce what is called angle iron, and iron bars of the varied forms now so

common, and used in such large quantities, more especially for the rails of railways. In our day the amount of iron used in this manner is prodigious, and the different kinds of rolled iron required for ship-building form no inconsiderable item in the great account. In Plate V. will be seen some of the forms most commonly used in ship-building. Angle iron, as its name implies, is a bar whose section forms two sides of a triangle; at the inner part of the angle it is formed with a curve so as to be much thicker than in the arms. The arms are nearly of equal thickness, and the outer edges are slightly thinned off. These bars are bent and worked into the various forms required in ships, with great skill and accuracy by men called angle iron smiths; they are then punched with holes, generally about the centre of the arm, and by the rivets inserted in these holes the angle iron is attached to the plates of the ship. The dimensions are usually given in the specification of a vessel in this form, viz.:—3 in. × 3 in. × $\frac{1}{2}$ in. This means that each arm of the bar is to be three inches from the angle, and the thickness in the centre of arm, or at the rivet hole, half-an-inch.*

As angle iron is generally applied for the ribs of a ship, the arm which is perpendicular to the surface of the plates is that which is in the position to afford the greatest stiffness to the shell. On this account, angle

* As a proof of the necessity of some definite rule upon this point, I may mention that I was lately engaged in an important arbitration relative to the fulfilment of a contract in building a new ship. A question was raised as to the proper place to measure the thickness of angle iron. Some stated that near the root was the right place; others, that the centre of the arm was the point; while others contended that near the outer edge was the true place. I, however, do not hesitate to state that the rule now given is the right one.

iron has been rolled with arms of unequal lengths—that the greatest strength may be obtained from a given quantity of iron: thus various forms have been produced, as shown in figs. 1, 2, Plate V.; others of equal sides are shown in figs. 3, 4, 5, 6. These are all brought to a perfect square at the angles, but others are rolled with a curve at this point, as figs. 7, 8. Another form, fig. 9, is the subject of a patent obtained some years since by Messrs. Vernon and Kennedy of this town, and was at one time much used. The object sought to be obtained, viz., to give more substance to the projecting arm, is quite correct in principle, but its disuse is probably owing to the reluctance of the manufacturer to depart from the usual forms, and to the difficulty thus occasioned of obtaining it. The same gentlemen also included in their patent other forms—fig. 10 is one of these, and resembles the letter Z; it was intended to supersede the use of reverse angle iron, but the difficulty of rolling it in long lengths has prevented its adoption. Iron is also rolled in the form of the letter T, figs. 11, 12, and is therefore called T iron; it has frequently been used in ship-building, but has not become general; it is much more difficult to roll than angle iron. Fig. 13 is called bulb iron, and is used almost exclusively for deck beams, as shown in Plates III., IV.

The quality of the iron of which the rivets, angle iron, and plates are made, becomes a question of serious importance, corresponding in some degree with the value to be set on different qualities of timber in building a wooden ship. With respect to the angle and rivet-iron, the usual tests are easily applied; both are subject to the action of the fire and the hammer, and if

of inferior quality opportunities are given for observing it; the bars for making the rivets may be easily bent while cold, an almost infallible test of their quality: but the plates in large vessels are differently circumstanced, they are not much tried while working, and their quality, therefore, without care, may pass unobserved. In making large plates, however, good iron is requisite to insure soundness, and any want of this may be detected in punching or shearing.

We should not, however, rest satisfied that we have attained in the present mode of manufacturing iron the highest degree of excellence. Iron is susceptible of changes in its chemical condition that produces effects of the most astonishing character; for instance, when iron is converted into cast or blistered steel, which is done by a simple process of the combination of the carbon of common charcoal under heat, its power to resist tension is increased from 25 tons to 60 tons, as the breaking point of a bar having an area of one square inch.

A process has been discovered by Messrs. Shortridge, Howell, and Jessop, of Sheffield, by which they produce nearly the same results by means closely allied to the manufacture of steel. It is called Howell's Homogeneous Metal, and an inch bar on being tested at the Liverpool Cable-testing Machine, broke with a strain of 53 tons, rather more than double the best English bar iron, and nearly equal to that of cast steel. The iron thus converted is ductile, malleable, and welds with facility; besides having other properties adapting it to iron ship-building. I am informed by the makers that its price, for large quantities, may in time be reduced to 30*l.* per ton; while iron plates are, at their present

rice of about $10l.$ per ton, and as less than half the reight is necessary, the cost is not widely different, rhile the advantages resulting from the difference of reight are very importaut. The power of this metal o resist oxidation and the action of fire, are also said o be very superior to common iron. From all these auses, a confident expectation is held out that its mployment in ship-building may not be far distant.

I do not here give any opinion as to the result, but raw attention to it as a subject of great interest, in he promotion of iron ship-building, and trust that nprovements in this direction may not be overlooked.

Machines and Tools Used in Ship-Building.

I have elsewhere alluded to the fact that good workianship is, if possible, more important than correct roportions in scantling, and it follows as an almost ecessary consequence, that in iron ship-building we hould avail ourselves of the aid of machinery wherver such means can be applied. Timber ship-builders ave not overlooked this subject, and very beautiful daptations of machinery for sawing both straight and rooked timber, and for other purposes, have been put ı operation. This important agent has been largely sed in working iron, but generally in a rude form, nd is I think capable of a more extended as well as ıore perfect application. In the manufacture of plates, ngle iron, and rivets, machinery has long been in use, ut for the preparation of iron in the process of shipuilding the introduction of machinery has been slow nd imperfect, and consequently the work itself has requently been laborious, irregular, rough, and some-

times unsound. This statement may, perhaps, be resented by some who have made great efforts to complete their work as perfectly as possible, and have accomplished great improvements, but in no branch of science of equal importance has the application of machinery made less progress, or its careful adaptation been less studied than in iron ship-building. This is partly owing to the difficulties of the case, to the exposed nature of the work, and to the apparent impracticability of performing some of the most important operations by any conceivable appliances, such, for instance, as the process of riveting the plates and ribs by steam power. But though there are some operations which at present appear to be out of the reach of the machine-maker, yet this impression should not cause us to relax our efforts to accomplish as much as possible.

I shall now present the reader with a description of such tools and machinery as are in most common use.

The Shearing and Punching Machines.

The plates being ready for the workmen, are carefully measured and examined. Those which are not exactly of the form required are taken to the shearing machine, others are to be curved and bent; these are subjected to a pressure in the bending machine, while all have to be punched for the rivets, and the outside plates require that the holes shall be tapered or counter-sunk, as described under the head of rivets and riveting. The first machine, then, is the shearing machine, but as this is frequently connected with the punching press, as shown in Plate XV., figs. 1, 2, 3,

I will endeavour to describe both together. There are a great variety of plans for these machines, but it is only necessary for me to describe one of each, and I therefore select that which appears to me to be well adapted to the work to be performed.

The great frame, A, which contains the whole, is generally made of one massive casting, of several tons weight, the form of which is best seen in the drawing. Motion is given to a strong horizontal shaft, F, by the ordinary pulleys, straps, and wheels, marked respectively B, C, D, connecting it to the steam power. A fly wheel, E, is also employed to give the accumulated impulse required in such machines. At each end of the horizontal shaft, F, is an eccentric, which gives motion to the parallel guides, I, into which the cutter or punch of the respective machines is fixed. These eccentrics are not shown, but work inside the frame, at the parts marked *f*. For the shearing machine two large cast-steel cutters, G, are prepared, each about a foot long, one being fixed in the lower part of the machine, and the other attached to the parallel guides and worked by the eccentric before named. These cutters are so placed as to meet each other in an angular position, similar to the two edges of ordinary shears, and thus are capable of making cuts at each motion of the machine, from four to six inches in length, through a plate about an inch in thickness. *

The plates are then marked for punching in the manner before described, and are held by two or more

* A few years ago, I saw the first trial of a large machine at Messrs. Thornicroft's iron works, Wolverhampton, made for shearing the edges of large plates at one cut. I think the plate thus sheared was nine feet long, and three quarters of an inch thick.

men in a horizontal position at the press, whilst another man, sitting on a stool, guides the plate so that the punch shall fall exactly on the round white mark.

The round part of the punch with which the hole is made is about an inch and a quarter long, and flat at the lower end; it is of the best cast steel, is turned cylindrical, and properly tempered; the upper part of this tool is so formed that it can be attached to the large parallel slide, I, that is set in motion by the eccentric on the horizontal shaft. Under the punch is the die, K; this is a small circular piece of iron, with the upper part of steel, having a hole through it a little larger than the punch. The correct position of the die under the punch is adjusted by four horizontal screws, pressing against its sides at opposite points.

Some difference of opinion is entertained as to the relative diameters of the punch and the die; in practice the punch for thick plates should be about three-sixteenths of an inch less than the die; for thinner plates, an eighth, or even a sixteenth of an inch less. Upon the amount of this difference depends the degree of taper in the hole, for the side on which the punch enters will correspond with the size of the punch, while the lower portion of the piece forced out of the plate will correspond with the hole in the die, thus making a tapered hole. This peculiarity, if carefully attended to, may be made available to a useful end, by giving the rivet, when compressed into the hole, the form of a double cone; and great care should be taken to punch the hole from the inside, or the side next the plate to which it is riveted, that the taper in the hole may be in the direction favourable for the rivet.

The largest hole punched in these machines seldom

exceeds an inch and a quarter in diameter, through a plate an inch thick, the drilling machine being usually employed for larger holes or thicker plates. The machines are generally regulated to punch about 18 to 20 holes per minute, the interval between each stroke of the machine being required for the men to shift the plate. Another peculiarity has to be noticed. After the punch has penetrated the plate, it would be difficult to withdraw it, as the plate, if not very heavy, is lifted from the die in the upward motion of the punch; to obviate this a small arm, L, partly encircling the punch, and fixed to the machine, comes in contact with the plate, and prevents it from rising, and it is thus easily disengaged. Small punching presses, placed on wheels, are frequently used, and are employed in the lighter work required for the outfit of a ship; these can be taken to the vessel, and are worked by hand.

Other tools are used for punching or drilling holes in plates by hand, under circumstances where the fixed machinery cannot be applied.

Plate-Bending Machine.

This machine, shown in Plate XV., figs. 4, 5, was originally intended for bending plates having an uniform curve throughout, such as the plates of a common cylindrical boiler, but by a little ingenuity the workmen made use of it to form the peculiar curves in the lines of a ship.

The bending machine consists of two strong cast-iron frames, F, united at the lower part by a strong cross tie, G, made in the form of the rolls, but attached to the frames at each end by the flanches, H. The

three rolls by which the plate is bent are marked A, B, C. Fig. 4 is the side elevation, and fig. 5 is a transverse section of the machine. The rolls are driven by the pulleys, D, and the small shaft, E, on which is staked the pinion, I, working into the spur wheel, K; on the spindle which bears the latter wheel are two pinions, one at each end, and these again drive the two lower rolls, B, C, by means of the wheels, L.

Thus two only of the rolls are driven by the engine, the third, generally the upper one, being left free. The journals, however, of this roller are raised and lowered by the screws, M. Thus the distance between the centres is varied, and a plate, N, passing in between the rolls, A, B, in the direction of the arrow, and out between A, C, will be more or less curved as A is more or less pressed down in contact with B and C; or if the roller, A, is elevated more at one end than at the other, the plate will partake of the varying curves of a cone; or, again, the plate may have an elliptic, parabolic, or other curve, given to it by the men dexterously altering the position of the roller, A, while the plate is passing through it.

In these machines the plates are generally bent while cold, and thus much time and expense are saved.

In some cases short rollers, having angular grooves in them, have been added to the ends of the spindles outside the frames, and by these means angle-iron frames have been bent; but the process for bending the frames of the ship before described is usually preferred.

Drilling and Counter-sinking Machines.

Several of these machines are required in the iron ship-builder's yard; they are used for drilling holes in the stem and stern posts, and in the solid keels, or in masses of iron where the punching press cannot be used. They are also required for counter-sinking the holes for the outside rivets in the hull.

These machines cannot be too simple, and I do not agree with those who would recommend the more scientific but more expensive and more delicate drilling-machine used by engineers. Those required for ship-building are best which are attached to two cross-beams, bolted to two of the upright pillars of the sheds; these pillars, being eight or ten feet apart, admit of room for the plates or large frames being easily moved about under the drill. The machine shown in Plate XVI., figs. 3, 4, is attached to the pillar itself: it consists of a main spindle, A, to the lower end of which the drill or tool for counter-sinking, marked B, is secured; this spindle is driven by the wheels, C, and pulleys, D, and can be raised or lowered at pleasure by the handle, E, turning the wheels, F, which act upon a rack at the back of the main spindle, the weight of which is counteracted by the balance-ball, G, over the pulley, H. The plate being laid on the table, I, the man by turning the handle, E, causes the spindle, and consequently the drill while revolving, to press down on the plate.

The tool for counter-sinking is simply a broad pointed drill, which is pressed down into each hole, and thus makes it conical to the required depth.

Several kinds of hand-drills are also used when required.

Machine for Cutting Angle-Iron.

As the common shearing machine is not suited for cutting angle-iron, some simple plans have been contrived for this purpose, and I submit the drawing of one in Plate XV., fig. 6, that seems to answer the purpose well. The frame, A, is similar to that of the shearing machine, and the shaft, F, which works the cutter, G, is set in motion by the usual means. The cutters are placed at right angles to the shears, and are used in the manner before described for cutting plates. Their form corresponds with the angle-iron which they are intended to cut. These machines need no further description, as they will be readily understood by reference to the drawing.

Riveting by Steam.

I have before described the process of hand-riveting, and it is by this process that the greater part of iron ship-building must be performed. As, however, there are some parts, such as the floorings and deck-beams, that can be carried to a machine to be riveted, ship-builders on a large scale may find employment for one of them. Mr. Fairbairn, of Manchester, was, I believe, the first to apply steam-power to riveting, and he accomplished this by giving motion to a die in a horizontal direction, pressing against a similar die fixed in the head of a wrought-iron pillar, about four feet high, which sprang from the same base as that on which the other part of the machine rested. This machine did its work well; but another machine has been patented by Messrs. Garforth, of Dukenfield, which has advan-

tages over it, and is now much used. This machine is represented in Plate XVI. Fig. 1 is the side elevation of the machine, and fig. 2 the plan; A is a short steam cylinder, about thirty-six inches diameter, supported on the frame B, having C as the foundation, from which springs the pillar D, on the head of which is fixed a die, as before described in Mr. Fairbairn's machine. In the cylinder is a piston, having a rod, E, communicating with the movable die, F. The steam being admitted to the cylinder by the handle, G, moving the valve, H, the die, F, is forced forward with great power. The ends of both dies are made concave, and of the form usually given to rivets. The plates to be riveted are suspended from a crane, and are brought between the two dies at I. The operation of riveting then begins; little boys are here again employed to bring the heated rivets, which, being inserted into the hole, the plate is guided so that the rivet is placed opposite the die, and the steam being let on, the die, F, is pressed forward upon the red-hot rivet. The head is thus formed, and the plate most effectually closed.

The pressure of steam on the piston being about 50 lbs. per square inch, the force given out is equal to upwards of 20 tons. The makers state that six rivets per minute can be put in, while by the hand-processes twenty per hour is the work of one set of riveters.

Where such machines can be used, the work must be sounder than when the rivet is driven by the old method. The process of cooling takes place after the head is formed, and the plate is consequently still further compressed by the contraction of the iron. The great advantage of this has before been stated,

when describing the experiments of Mr. Edwin Clarke at the Britannia bridge.

The Air Furnace.

The various appliances for heating iron in the process of iron ship-building next requires our attention; they are of the simplest kind, but, like everything else, require the finishing touch of practical experience to adapt them most advantageously to their work.

The smith's fire needs no description, being similar to that used by smiths in other operations. All well-arranged smithies have the ordinary fan-blast conveyed by underground pipes to each fire, and sometimes this blast is carried to small hearths in different parts of the yard to heat rivets.

For the purpose of heating large plates and long bars of angle-iron, uniformly and quickly, hot-air furnaces are formed of brick; two are generally placed together, and the flues from them lead to the same chimney. One is made wide, say 4½ feet by 10 feet in length, suitable for heating plates; the other is made long and narrow, say 2 feet wide by 25 feet long, and is required for the angle-iron bars that have to be bent in making the frames. A drawing of this furnace is given in Plate XVII., figs. 1, 2, and will sufficiently explain both kinds, allowing for the simple differences of the length and breadth. Fig. 1 is the longitudinal section; fig. 2 is the end at which the iron to be heated is inserted.

The furnace, A, is constructed with bars in the usual manner, and a pan, B, filled with water, is sometimes placed under it, which, cooling the ashes as they fall down, prevents the great heat from the under side melt-

the bars. This furnace is fed with coals, the flame which passes along the chamber C, and over the brick d, D, on which the plates or bars are laid. The roof er the whole is a brick arch, about two feet from the ed, acting by reverberation, to concentrate the heat pon the iron. The flame and hot air then escape down narrow flue, E, situated across the mouth of the furnace and leading by the main flue to the chimney. The end at which the plates or bars are inserted and withdrawn is closed by a door, F, framed of iron, and inclosing fire-bricks. This, being very heavy, is suspended by a chain, and this chain is attached to a lever, G, having a balance weight, H, suspended from it, that the men may have less difficulty in raising and lowering it.

The object of turning the flue downwards is to bring the flame as much in contact with the iron as possible, at the part most remote from the fire, and thus heating it equally throughout; an iron sill, I, is placed across the doorway on which the angle-iron slides, as it is drawn in or out of the furnace. As the expansion of the brick-work, from the excessive heat within, would immediately crack the walls of the furnace, it is always inclosed by cast-iron plates, and bolts are run across it through the brick-work.

THE RIVET HEARTH.

This is a necessary and useful appendage in ir ship-building; one of these is required for every t or three gangs of riveters; they are managed entir by very young boys, who work the bellows and carry rivets. This is the first stage in the career of m of those men who afterwards perform the var

operations in iron ship-building; it is a rough service, but not ill-adapted for training them to their subsequent hard life. The rivet hearth must be placed near the spot where the rivets are required, as any delay in carrying them would cause them to cool below the temperature required in riveting. It must, therefore, be made portable, and is to be seen perched up in every accessible part of the ship.

I have added a drawing of it in Plate XV., fig. 7. The hearth itself, marked A, is formed of a light iron frame and some plates roughly put together; on a separate frame, B, is placed a small round bellows, so formed that the motion of the handle, both upwards and downwards, acts upon it. The centre and lower boards are stationary, the upper and third boards move alternately with every motion of the handle, and thus produce a double blast with very little increase of labour. I describe this as being what, in my opinion, is the best of the various plans that have been used for this purpose.

Sliding Keels.

In consequence of the lightness of iron ships, they were, at an early period of their history, used for purposes where a light draught of water was necessary; but as such vessels were also sometimes required to put to sea, and work under canvas, sliding keels, as shown in Plate IX., figs. 1, 2, were introduced, corresponding with the Dutch lee-board, and other similar contrivances. The sliding keel is, however, well adapted for iron ships, as the trunk necessary to contain it is easily made. To prepare for this keel, an iron trunk, 6 feet to 8 feet long, and about 10 inches wide, is made in

centre of the vessel, in the line of the keel; it ends from the bottom to the deck, and contains the ling keel, formed of timber, and bound with iron. iis keel is raised and lowered by a winch on deck. When the vessel is in shallow water it is drawn up, id when in deep water it is allowed to project about alf its width below the bottom, and thus form an fficient lee-board for the vessel when under canvas. If from neglect, or from accidental causes, this keel should strike the ground, it is made of such a form as to cause it to rise up into the trunk. Fig. 1 is the side view, and fig. 2 the transverse section of the keel and trunk. The arrow shows the direction in which the vessel sails, and the object of the inclined form of the bottom of the keel will therefore be understood.

Water Ballast.

The desirability of using water as a means of ballasting ships is so evident, that many attempts have been made to introduce the practice; but to do so effectually, some conditions are necessary to be observed that do not attach to ballast in a solid form. In water ballast the reservoir must be quite full, to prevent the water from following the motions of the ship, and thus being worse than useless; it should also be placed below th level of the water outside, that it may run into th vessel and fill the chamber without trouble; and lastl that it should interfere with the stowage of the ship little as possible.

The plans for this have been various, and its i portance was considered sufficient to warrant a l inquiry, and some able discussions, at the Engine

Institution during some of its late meetings. The employment of large water-tight bags has been attempted several times. These, when empty, are stowed away in large boxes, and when required for use are spread out in the holds, and being connected together by a hose, are thus filled. The objections to this are, that the bags being very heavy require great labour to move them. I have not heard that any great measure of success has attended them. Iron tanks have been much used, but these must be very large to contain sufficient water to be effectual, and they require to be moved before the ship under them can be cleaned and painted.

Some builders have made a large tank by two bulkheads across the ship, and which, when the ballast is not required, can be used for coals or cargo. This has the advantage that no stowage is lost; but such tanks are difficult to fill, and to keep tight on the top when filled; it is also too high in the vessel to be so efficient as it would be if lower. Iron ships are, however, peculiarly well adapted to another mode, which I have introduced into several vessels, and of which I give a drawing in Plate IX., fig. 3. This plan has been adopted by vessels employed in carrying coals, or other heavy cargo, where little or no back freight is to be had. The specification of the vessel from which this drawing was taken will be given in another place. She is built for carrying coals or iron ore; she is 630 tons builder's measure, and will carry about 800 tons of dead weight, and her main hold is even then not filled, so that the room for the water ballast can be spared. Under the main part of the ship the bottom is made double, of any required depth,—in the present case three feet, or about

double the usual depth of the floorings. The floors are formed in the usual manner with angle-iron plates, but the side frames are divided at the bilge; this is done that a strong angle-iron may be attached to the sides of the vessel as shown at A, and to which the plates that form the inner shell may be riveted, and made perfectly water-tight; these plates are also riveted to the top of the floors, and to the bulkheads. Manways are made in the top of this great chamber, and in the floorings, so that boys can be sent in to clean and paint.

To compensate for the break in the side frames, each of these is made with a knee, about two feet long, and riveted to the inner shell, and a small angle plate in the corner has been latterly added. The fine parts of the vessel under the forecastle and after cabin have also been made water-tight, and thus all combined make efficient ballast for the ship, equal to about 270 tons, for the greater part low down in the vessel. It will be easily seen that all the chambers can be entirely filled if the sea valves are opened before the vessel is quite discharged; and by another valve being opened the water flows into the engine compartment, where large pumps are provided, and worked by the donkey engine, for the purpose of discharging it.

Two other advantages may be named as resulting from this plan. The first is, that it forms an almost entire double bottom, giving great strength and safety to the ship, the proof of which was lately shown in a vessel which ran on to the rocks near Holyhead, and came off with one or two holes, but which caused no danger to the vessel. The second advantage is, that the spaces between the floors and the fine ends of

the ship, which are useless for stowage, are made available for ballast: this cannot be done where separate tanks are used.

Great care is required in riveting the frames to the upper plate of the reservoir, as the want of this has caused a leakage.

It will also be advantageous to run a water-tight division down the line of the keel, to prevent the water from flowing to one side when partially filled, and thus heeling the vessel on one side.

IRON VESSELS CONSIDERED AS A COMMERCIAL QUESTION.

Under this general head it is intended to submit some remarks on the peculiarities of iron vessels, and institute a comparison between them and timber-built vessels, embracing those features in each that principally affect our commercial interests.

What, then, are the points which it is the province of the builder to study and attain? What are the objects most desired by the merchant in the choice of a ship? These are—

1. Strength combined with lightness.
2. Great capacity for stowage.
3. Safety.
4. Speed.
5. Durability.
6. Economy in repairs.
7. Cost.
8. Draught of water.

It is only by comparison that the value of anything

can be estimated; everything must be judged of relatively with something else, having some objects in common. The qualities of ships can only be estimated by a comparison with other ships. Experience proves that iron vessels possess advantages under all the heads above stated in so eminent a degree as to render them superior to wooden vessels; and I shall address myself to each point in its respective order:—

1.—Strength Combined with Lightness.

This subject involves two considerations, the strength of the materials and the mode of uniting them.

The great strength of malleable iron to resist strains in every direction is well known; but to those who are not conversant with the subject, the extent to which this advantage may be carried is not at first apparent; or how the material may, from comparatively small pieces, be so combined in large masses, as to form the ponderous body of a ship; and they are thus too apt to prescribe a limit to its use. An opinion, indeed, was generally entertained, that iron might be suitable for small craft, but was inadequate for the construction of vessels of heavy burthen. This, however, is a supposition so erroneous, that the reverse would be much more correct; for large vessels will afford the best practical demonstration of the superiority of iron for ship-building. In the application of timber, obstructions increase in a ratio proportioned to the increased size of the vessel to be built. How often has the ship-builder the greatest difficulty in obtaining timber to suit the varied curves of our finest ships! How often is the country despoiled of its noblest ornaments

by the tempting prices he is compelled to offer for its most magnificent oaks, the largest of which are frequently insufficient for his purpose! How are his brains racked, and his patience tried, in seeking for crooked timber necessary to frame a sharp floor, or a square bilge! How often is he obliged, though he knows it to be injurious, to scarph the frames, for which no timber can be found sufficiently large to enable him to avoid such defects! And is not this one cause, amongst others, why our building-yards are empty, while our ports are filled with ships from other nations, in which timber is more plentiful and the choice more extensive?

But how stands the case when we turn to iron? Where is the frame, even of the most intricate form, that our smiths cannot mould? Where the frame or beam so large that iron cannot be found of which to fashion it, and that too, if need be, without a scarph? Here there are no knots, no sap, no cutting across the grain. Here there is no useless timber, placed merely to *fill in*, or to cross butts. Here every inch of material is of service, and every scrap applied to some useful end.

Iron has great power to resist tension in any direction, as is shown by Mr. Fairbairn, who proves that but little difference in its resisting powers is to be perceived, whether the strain be applied in the direction in which the plate is rolled, or across it. Iron has also, to a high degree, the power of resisting compression. Timber, it is admitted, has great power to resist tension in the direction of the grain, but is very deficient in strength across the grain; and its power to resist compression is also very limited, and when

exposed to moisture its strength, in this direction, is reduced one-half, as has been proved by recent experiments. Again,—timber, after being some time in use, becomes brittle, and is but little disposed to bend. Good malleable iron, on the contrary, may be bent double, even when cold, and does not become brittle with age, except when converted into an oxide. The ease also with which iron beams and frames can be wrought, and the facility of obtaining them of any dimensions in one piece, overcomes one of the greatest difficulties in ship-building.

It has before been stated, that the power to increase the stiffness of the hull, when built of iron, is unlimited: and provided the shell has originally been made sufficiently thick, additional strength may, at any time, be given to the frame. Of this fact we have had many instances during the progress of iron ship-building.

The strength of beams to resist vertical pressure increases as the square of their depth. The advantages to be derived from this may be simply illustrated. By making a beam 17 inches deep instead of 12, we double its strength, but its weight is increased in the proportion of only 17 to 12; or by doubling the depth of the beam, we increase its strength four-fold, but we only double its weight,—and so on to any extent.

As we have sufficient proof that the utmost strength that can be required in vessels may be obtained from iron plates, it only remains to dispose of them in the position in which their strength is found to be most available. If the shell be sufficiently strong to resist all the strains arising from tension and compression, it is only necessary to stiffen it so much by adding other plates perpendicular to those of the

shell, that it shall not deviate from its correct or original form.

If we view the subject with respect to very large vessels—sailing ships or first-class steamers, in which intermediate decks are not only not objectionable, but requisite, and in which entire or partial bulkheads are multiplied without causing much inconvenience—we have, in iron, the means of dividing the shell into small sections, affording the strongest supports directly opposed to the strains that tend to disturb the form of the plates, and in the direction in which they can least resist such strains. The sides between these decks and bulkheads are strengthened by the ordinary mode of framing. In addition to this, the lower part of the vessel may be intersected by longitudinal divisions; and these decks, bulkheads, and subdivisions are not only securely fastened to the shell, but to each other,—the whole thus becoming a mass of almost irresistible strength, meeting the strains in whatever direction they arise, while, at the same time, the weight is far below that of a timber vessel of only moderate scantling, and the room for stowage much greater.

A comparison of the different modes of fastening timber and iron vessels, and uniting their separate parts, is as favourable to the latter as the question we have just considered. We will take, in the first instance, the case of an expensively copper-fastened timber-built ship. Copper and iron bolts are used to secure the frames to each other, extending in some cases through the keelson, floorings, and main keel, and in various other parts. But what, generally, are these bolts? They are plain bars or rods of copper, driven into the holes prepared for them: a washer is

then slipped over the other end, and the carpenter, with a small hammer, forms on each a kind of head, pressing the washer firmly down into the timber. All this is very well so long as no very severe strain takes place, but is found very deficient for the binding together and support of large vessels. Of this fact we have abundant proofs. I have seen a vessel, nearly new, put into the graving dock with several of her bolts projecting out from her bottom, being started or drawn, and rendered quite useless by the working of the ship.

A most elaborate system of bracing by iron straps, knees, and bolts with nuts, in addition to the ordinary knees, diagonal internal planking, stringers, &c., is now pursued. To the usual tree-nails used to secure the planking are added bolts, either of copper, iron, or composition, and great additional strength is thus imparted. But the grand objection still remains. The bolts do not accord with the materials they fasten together, and the wood is so soft that when a severe strain arises, a general yielding takes place, by the bolt-heads sinking into it, and the wood itself giving way to the pressure it receives from the neighbouring parts. In proof of this it is only necessary to examine the copper sheathing of a large vessel after a trying voyage, when the waving surface too often betrays the defects within. This effect of straining is most perceptible in steam vessels, particularly under the paddle beams, and sometimes abaft them. The creaking of a timber-built ship, too, so distressing to landsmen, and adding so much to the terrors of a storm at sea, is the result of the unceasing motion which takes place in the seams, acting on the internal timber-work, and particularly on the cabin partitions and bulkheads.

A wooden vessel is made up of a great number of parts of various forms and sizes, placed in different directions, which, like the stones in an arch, are dependent on each other for support. If one becomes loose, the whole structure is more or less endangered. This is evident from the fact, that much of the stiffness of a wooden vessel depends on the caulking of the outer plank.

I may add, in corroboration of these facts, that it is the general custom with builders to leave the gangways of the bulwarks in wooden ships unfinished, lest the hull should so much alter its form by settling in launching, that the rails would not again fit their places; and no builder would willingly copper a vessel when new, but rather allow her first to find her own position in the water, as she would then be less liable to wrinkle the sheets. The defects noticed are indications of weakness and tendency to straining, but they are so common, and, at the same time, inseparable from the construction of ships, that no one deems them worthy of notice as objections; and I perhaps expose myself to the chance of being considered an alarmist by merely alluding to them. My only object, however, is to state the truth, and to leave others to judge for themselves.

Mr. Creuze (to whom I have before alluded), in his paper on iron vessels, thus reasons :—" Two questions naturally arise; first, What are the advantages or disadvantages of the substitution of iron for timber, in the construction of ships?—and, secondly, To what limit may this substitution be advantageously carried? Amongst the advantages are the employment of a less costly material, of which the supply is inexhaustible,

and for which supply we are totally independent of other nations; also, the greater durability of the material, not only from its relative durability with that of timber, but from its requiring no such metallic sheathing to protect it from the ravages of worms. Also the greater durability of the structure, as a whole, in consequence of the greater permanency in the perfect combination of its several parts, arising from the fastenings being of the same texture as the portions of materials brought into connection. The metallic fastenings to a timber-built vessel act, it must be remembered, not only chemically, but also mechanically, to accelerate her destruction so soon as the close connection of the several parts is at all diminished."

The question as to the best method of constructing the whole fabric may be discussed under two heads. First, that the whole shall be made strong enough, without employing an unnecessary quantity of iron. Secondly, that no point should be made relatively weak by making some parts unduly strong.

That an unnecessary quantity of materials is injurious is evident: it increases the cost, and practically displaces cargo exactly to the extent that the weight of the ship exceeds what is really requisite. But, on the other hand, in large sea-going ships, sufficient strength is so important, and as the turning-point where excess of strength commences, is so difficult to ascertain, it is the leaning of every practical mind to "make sure," by a tendency to an excess in strength; but this will be worse than useless, if judgment be not exercised, and an uniform strength be not applied.

Ships are elastic bodies, and one great element of their strength consists in a uniform elasticity through-

out. Imagine a beam, which is also an elastic body, being made unduly stiff at the ends, the elasticity or spring which is so essential in sustaining shocks or unequal weights, is confined to the weaker points, and that which would have been sufficient, had the elasticity been uniform, is insufficient when this peculiarity is not attended to. On these grounds, it is of importance that the strength of a ship should be distributed with equality throughout; it will also be evident that the weights of the ship, as well as of the cargo, should be distributed with reference to the form of the hull, and the consequent buoyancy which has to sustain each portion of it. Nothing can be more injudicious than the plans which are often to be seen in regard to this subject, and may be observed very strikingly in some of our long fine ships, where the weight of forecastle, bowsprit, anchors, chains, &c., is placed without any reference to the amount of buoyancy under them. The immense leverage thus occasioned acts immediately on the midship body of the ship, and is no doubt the origin of derangements frequently ascribed to other causes. I mention this here, as being especially applicable to iron ships, in which fineness of form has been carried to a much greater extent than in wooden ships.

In the early designs for iron ships, it was usual to diminish the thickness of the plates, and the strength of the frames in the fore and after bodies, and consequently to reduce the weights in these parts; but this system has been departed from, and an opposite one is required by the new regulations for the classification of iron ships at Lloyd's. I cannot help thinking that this change was made upon insufficient grounds, pro-

bably because some ships had shown weakness in the entrance, or the after-run; but experience has proved this defect to have arisen from want of internal fastenings, which in iron ships are of the simplest character. To this subject I have before alluded, but again urge it on the attention of iron ship-builders.

The objections arising from the use of fastenings of a material so totally different from that of which the hull is composed, are entirely removed in iron vessels. In the first place, the outer shell of the vessel is composed of a series of plates, so riveted together that its strength is nearly equal to what it would be were it possible to form the whole of one plate. This shell is independent of all indirect means for preserving its completeness. It forms one grand whole, of the same material throughout, and that of the strongest kind. This shell is stiffened, as before described, by ribs crossing the joints of the plates at short distances apart, and giving an additional security. Beams, knees, bulkheads, all are brought together in one firm mass, and united by numberless short unyielding rivets. I may venture, indeed, to say, that more real serviceable fastening is often employed in the space of a few inches, in an iron vessel, than is in most instances brought to bear on one entire beam of a timber-built ship.

When my first small treatise on this subject was written, it was not difficult to collect some of the most remarkable incidents then known, as proofs of the great strength of iron ships; but those then recorded have been so often since surpassed, that I will omit them here, and in their place name a few facts of more than usual interest, that have occurred since then.

In 1845 I communicated, by a short paper, to the Institution of Civil Engineers, an accident that took place in the harbour of Cork, by which the *Vanguard*, a paddle-steamer, of 670 tons and 300 horse-power, went on to a bed of rocks, where she lay for some time, beating severely. The stern was broken, and the bottom much damaged; but so little was the vessel strained, that, when floated, the engines seem to have remained unmoved, and worked as well as ever. She was afterwards effectually repaired.

The well-known case of the *Great Britain*, for many months ashore in Dundrum Bay, exposed to a whole winter's gales, has never been equalled as a case to illustrate the strength of iron ships. I was one of the surveyors appointed by the Underwriters to estimate the damages; and although we found that every part of the bottom had been battered and damaged by the rocks upon which it was beaten, yet the form of the vessel remained unaltered; and it was difficult to perceive the slightest strain in the upper sides, or to detect any alteration in her form.

The magnificent steam ship *Tyne* affords another case well known to the public, as having excited deep interest, when run a-shore during a fog, with a large number of passengers, arriving from the West Indies. The accident happened on the south coast of England last year, and the vessel remained for several months exposed to the winter gales. She was at last rescued from her dangerous position, and taken to Southampton, where I saw her nearly repaired, and as good and sound as when first built. Her rudder and a large portion of her keel were torn off, and her floor was much injured by the accident; but no

perceptible change could be discovered in her general form.

One remarkable instance more will be sufficient; one indeed, which was accompanied by circumstances awfully significant.

It was a matter of much astonishment that no iron vessel had been built for the Mail service between Liverpool and New York; when at last the present well-known iron steamer *Persia* was laid down. On her *first* voyage last year she was preceded by the *Pacific*, a timber-built steamer belonging to the American Company, and both seem to have fallen in unexpectedly with large floes of ice; the result is too well known;—the *Pacific* went down with her immense living freight, not one left to tell the dismal story. The *Persia*, on the contrary, encountering a small iceberg when at full speed, split it in two, receiving no injury except by the fragments that floated into the wheels and broke several of the floats.

The power of iron vessels to withstand the action of the waves may be estimated by the fact, that when timber-built steamers have been wrecked, the hull and machinery have all broken up, while the iron boilers made of plates like iron vessels, alone remained to indicate the spot where the disaster occurred.

2. Stowage.

The stowage is the next question for consideration, and, though of great importance, it is less difficult to explain than the former subject, being simply a question of figures. The shell of a timber-built vessel is so much thicker than that of an iron vessel, that, with

the same outside dimensions, the latter is frequently 18 inches wider and 12 inches deeper in the hold than the former. Taking the most favourable part of a vessel—namely, in the centre of the length—in a vessel of 200 tons, the proportion in favour of the iron vessel will be as 5 to 6; but in the ends, which are drawn finely off, the disparity is much increased, making the proportion of the whole contents about as 4 to 5. Supposing, therefore, that a vessel built of timber could stow 200 tons, she would, if made of iron, have room for 250 tons. The total capacities of the largest vessels will probably not approximate nearer than as 5 to 6; making the iron ship of 600 tons burden not to exceed in outward dimensions the timber one of 500 tons. The advantage of this is very great, and enables an iron vessel to trade, and remunerate the owners, in cases in which a wooden vessel would not return a profit; for, if we suppose that the freight of a 500 ton ship would just pay the expenses required to navigate her, an iron vessel would leave the freight on the extra 100 tons as clear profit.

With steamers, the comparison is even much more in favour of iron. As the average cargo of a steamer is only, perhaps, about one-half of the load, in engine, cargo and coals together, an increase of one-fourth in her stowage adds 50 per cent. to her capacity for carrying cargo; so that to carry a given cargo, the iron steamer may be much less than a wooden one.

3. Safety.

The safety of a vessel is, in a great measure, identical with its strength; and the cases above adduced

with reference to this point as regards iron vessels, will be sufficient, I trust, to satisfy all reasonable minds. In addition, however, to their extraordinary strength, iron vessels afford protection both to life and property against the most awful accident that can befal a ship at sea,—namely, against fire. I admit that it can signify little to unfortunate passengers of what material the hull of a vessel is made, if her cargo, deck, cabins, and masts are consumed; as no one, who might escape the conflagration, could then remain in her. But, with ordinary precautions, it would be nearly impossible for a fire to take place, or to gain head, in the hold of an iron ship, provided the hatches were properly secured; for the bulk-heads make each division perfectly air-tight, and effectually stop out the atmospheric air, without which fire will not burn,—thus confining the injury, when it does occur, to the compartment in which it originates.

Iron vessels, from the nature of their construction, are more free from the risk of starting the buts, or opening their seams, in a long continuance of heavy weather. They are stiff under canvas, and all who have sailed in them speak of their extraordinary buoyancy,—qualities tending very much to increase their safety.

There is one source of risk to which iron ships are more liable than timber-built ships, I allude to the effect of a blow from a hard and pointed substance, such as the fluke of an anchor, or a sharp rock. These have been found to penetrate the iron plates more freely than through the planks of a timber ship, supported as they are by the ribs, which form an almost solid bed under them; but when accidents of this

kind do happen to iron ships they are easily repaired, and if the vessel is properly divided with bulkheads no absolute danger need be apprehended. When, however, the comparison is to be made of the strength of the whole fabric, it is largely in favour of iron.

4. Speed.

Shipowners are now becoming sensible of the value of fast-sailing ships, and an improved system is superseding that which has hitherto guided them in the choice of models. The old register laws, which caused more injury to our mercantile marine than those at present in operation are ever likely to repair, and which originated and fostered evils that it may require ages to correct, are no longer obstacles to improvement, and their abrogation affords us some hopes that we shall not for ever be left behind other nations in the speed of our vessels. As iron has become generally used for the purpose of ship-building, a much finer form has been adopted, without incurring the disadvantages that arise under the same circumstances, in even the most approved construction of wooden vessels. This has long been a settled point in steam vessels, and the knowledge of it is fast gaining ground in regard to sailing ships. The material being much lighter to attain the same strength, and occupying less space, the model of the vessel may be made finer, and better adapted for high speed, without a corresponding loss in the amount of stowage and carrying qualities. These assertions are not the result of mere theoretical speculation, but are derived from a long course of observations, guided by the opinions of many practical

men who have become converts to the adoption of iron as a preferable material to wood in the construction of vessels.

5. Durability.

It will be unnecessary to extend this portion of our inquiry by considering the progress of decay in iron vessels when employed in *fresh* water; but to direct our attention to the effect produced upon them by salt water, as a favourable result in the former case will not be disputed, if it can be established in the latter.

In 1842, I wrote as follows:—"It is, as yet, impossible to assign any period for the duration of iron vessels in salt water, inasmuch as they have not been tried for a sufficient time to enable us to ascertain this point with precision. The want of proof must, however, be considered favourable from the fact, that were their decay as rapid as that of wooden vessels, such a result would already have become manifest."

The difficulty even now is not much lessened; vessels of which instances were then given are still afloat and sound; and the few that have passed away, have given remarkable proof of the durability of iron ships, even in salt water. The *Aaron Manby*, the first iron steam vessel of which there is any record, built in 1821, was broken up in 1855. The *Marquis Wellesley*, built in 1824, is still afloat as before stated, though now much decayed. The *John Randolph*, built in 1833, is still in good order, having done a great deal of hard work. The *Garryowen*, built about the year 1834, is in excellent condition on the lower Shannon. The *Euphrates*, built in 1834 by Mr. Laird for the Euphrates' expedition under General Chesney, is still at work on the

Indus. The *Rainbow*, of 1837, is to be seen in the Thames, doing her work well. The *Nemesis* and *Phlegethon* are still doing duty in the East, carrying heavy guns, and doing efficient work, though only built originally for river navigation: and many of the earliest vessels, though much inferior in strength to those now built, will stand the test of close examination :—and what will be the durability of the large and strong vessels now built and building, when proper care is bestowed upon them, it is difficult to predict; but that it will exceed by a long period the average term allowed for timber-ships, can no longer be questioned. And the numberless vessels since built—some of which according to the average term of wooden ships, viz., thirteen years—may be called old, scarcely assist us in forming an opinion of their probable duration from the little progress yet perceived in their decay.

As oxidation is promoted by heat, the boiler in steam vessels should be kept as far as possible from those parts of the vessel which are above water, or means should be adopted to keep them cool by interposing non-conducting substances. The plates in other respects in the engine-room do not appear to be more liable to corrosion than the rest, thus exhibiting a result different from that which was expected. Care should be taken not to connect copper pipes to the shell; and, to avoid this, some have added short lengths of wrought-iron pipe, with flanches, and riveted them to the vessel.

The absence of motion, arising from strains in the joints and seams of a well-made ship, may be considered an important security against wear and tear. The durability of a substantial iron ship, always water-

borne, will mainly depend (accidents alone excepted) on the question of corrosion; and this again, in a great measure, on the care that is taken in cleaning and painting, which when duly exercised, will be found to be of much advantage.

We now turn to the consideration of the durability of timber-built ships. And where in the catalogue of objections, real or fancied, to iron ships, is there one to be found equal to that dreadful scourge to wooden vessels—the *dry rot;* the effects of which are too well understood by shipowners to require any lengthened remarks from me? I should not, however, do justice to my subject did I pass it over in silence. No age has been without its nostrums, its quackeries, and its "infallible remedies" for the *dry rot,* and no period has been so productive of them as that in which we live; but still the plague is as prevalent as ever. The dry rot in wooden ships (which finds no parallel evil in those of iron) is frequently as remarkable in the earliness of its commencement, as it is invariably rapid in its progress; and no appliance hitherto resorted to has, in all instances, been effectual to avert its insidious development, or to arrest its destructive progress. The tree which is intended for a timber ship is no sooner felled than the oxygen, which, during vegetation, is held in harmless combination, begins its work of decay. The gradual combustion and deterioration of the woody fibre supervenes; carbonic acid is evolved; and the wood, becoming carbonised, loses its flexibility and strength. The progress of this decay is sure, though, by care, its effects may be retarded; but, from the numerous instances of its rapid increase, even in well-built vessels, we are led to conclude that no human

foresight can prevent its poison from spreading, like a baleful epidemic, into every portion of the ship. How many stately vessels are now mouldering away under this destructive visitation, while their fine and graceful forms conceal the treacherous enemy within!

Some kinds of timber are much more liable to this defect than others, and its progress is much increased by neglect and a want of air. But when it has once commenced in a ship, her character for seaworthiness is lost, and she can no longer be depended upon; for it is too often found that she is weakened in the most vital points; that those parts, on which her safety mainly depends, are decayed; and that some unusual and casual strain is alone required to complete her destruction.

The action of iron fastenings is sometimes found to be as injurious to the wood as that of the wood is to the iron; and thus one of the main sources of support to a timber-built ship not only accelerates her decay, but is, in its turn, destroyed with equal rapidity by the wood. Fig. 1, Plate XXI., represents an iron bolt of an inch in diameter, which secured an iron knee to the oak rib of a well-known steamer in this port. The sound part was in the knee, and the decayed part in the wood. It was in its place only three years; was much above the water-line, and not near the copper; but was probably destroyed by the acid of the oak. This is a striking proof of the insecurity of iron fastenings when immediately attached to wood; but where iron is in contact with iron, the corrosion seems to be comparatively slow.

There is also another point connected with the comparative durability of the two materials, which is very favourable to iron. Oxidation proceeds no faster on

the surface of thick plates than on that of thin plates; so that plates of half-an-inch have at least double the durability of those of only a quarter of an inch in thickness. A large and consequently valuable vessel, if built with plates of proportionate thickness, will therefore be durable in increasing proportion to her size. On the other hand, the thickness of wood, either as applied to planking or framing, does not increase its durability in a like proportion, but from the difficulty of thoroughly seasoning it when it is of great thickness, or of admitting air to preserve it from damp, is rather detrimental, and thus the small vessel becomes as durable, or even more so, than the large vessel.

In immediate connection with this subject, is the question of the best means of preserving the iron from oxidation. Many scientific and practical men have, for many years, closely watched the success of the numerous projects that have been suggested for this object; but as it would be impossible to enumerate all the parties who have been thus engaged, I refrain from naming any; and this precaution is necessary, as it is not yet proved that anything has been proposed to supersede good oil-paint, put on when the plates are dry. Good paint becomes a perfect enamel, and while carefully preserved by periodical renewal, no sensible decay can be perceived. But to do this effectually requires great care in the first application, and constant watchfulness afterwards; the result, however, will amply repay the attention.

Good white lead paint is perhaps the best application,* but red lead is preferred, though, probably,

* Before the plates prepared for ship-building leave the works of the manufacturer it has been the practice to mark them with some figure or

without any satisfactory reason. Care should be taken that paint is applied under the frames before they are riveted to the plates, and that no wood should be allowed to come in contact with the iron without a similar thick coat of paint being previously applied. It has been customary, in some cases, to apply a coat of boiled oil to the plates and frames in the process of building, to prevent corrosion when they are necessarily exposed to the atmosphere. This is, doubtless, a wise step; but care must be taken that no oil reaches those parts which are to form the joints.

Iron ships will doubtless suffer injury from some descriptions of cargo; for instance, sugar during a West India voyage, will leak from the casks and get into the bilges; there becoming a powerful acid, it has been found to injure the plates. A simple remedy is, however, at hand:—if a small quantity of water from the sea be let into the ship daily and pumped out again, the strength of the acid will be kept down, and the ship remain sweet and clean.

The same observations apply to cattle, when carried for some days in an iron ship.

Another source of injury to the plates may be noticed. The violent action of bilge water during the rolling of the ship, has been found to wear indentations in the parts where its current has impinged with much force, the same, but less in degree, that is produced by a similar action on stone. This has been obviated by a thick coating of pitch, or common asphalte. Those portions of the vessel at the extreme ends just above

letter in white paint, that the ship-builder may know for which part of the ship it was intended. This mark has been known to remain after the ship has been often painted, and has been easily traced for many years afterwards, when the outer coat has been scraped off.

the keel, where the space is too narrow to admit of their being cleaned or painted, may be advantageously filled up solid in the same manner.

6. Repairs.

The wear and tear of well-built iron vessels (and I speak confidently from actual experience) are practically trifling, and the repairs are consequently light. This item, which in wooden vessels presses so heavily on the profits, is, in iron vessels, of but slight importance; and although the comparison will be found very favourable in iron sailing ships, the fact will be more clearly shown by reference to steamers. The usual calculation for a timber-built steamer is, that the expense of repairs will, in ten or twelve years, have equalled the first cost. In a well-built iron steamer repairs to the iron work will not, I believe, have become necessary within that period, provided the vessel has not been injured by accidents; and it is frequently more expensive to keep in repair the copper sheathing alone of a wooden vessel, than to effect the whole repairs in the hull of an iron vessel. The necessity before spoken of, for frequent and periodical painting the under part of the vessel, entails some expense and delay; but to meet this, it becomes incumbent on those in authority in our large ports, to provide convenient docks for their accommodation; and I suggest, for this purpose, the more extensive use of dry gridirons, which can be simply constructed.

In the event of accidents, the repairs of iron ships are extremely light, and in this respect also they bear a most favourable comparison with wooden vessels.

The cases that have fallen within my own observation are so numerous, and so decisive of this fact, that, were it not superfluous, many pages might be filled in recording them.

It is a great mistake to suppose that iron vessels are more difficult to repair than wooden vessels; and, in pursuance of this error, it is often urged as an objection, that should accidents occur to them while in a foreign country, no one could be found capable of making good the damage. But so far is this from being the case, that it is found that nothing is easier of accomplishment; for the injuries are generally external, and confined to a single spot, and may, in most cases, be sufficiently repaired by any ingenious man, if the ship be but provided with a few drills, some spare plates, bolts, and other necessary articles, which no captain should neglect to carry amongst his stores. Besides, when iron vessels become more generally employed, the necessary assistance and means will be found at all considerable ports and stations at which they may touch.

7. Cost.

The following remarks were written in 1842, and have been painfully verified by later experience, especially when a large class of iron sailing ships began to be introduced. The ruin brought upon the builders, and the injury done to the system, is still severely felt. I quote from my former work:—

"The first cost of iron vessels is next to be considered. The public, and frequently builders themselves, are under considerable misapprehension in respect to the comparative expense of wooden and iron vessels.

It is the general impression that iron vessels may be built at a much less expense than wooden ones; and some builders have, consequently, been injudiciously induced to take contracts at estimates too low to ensure them a remuneration for the use of adequate strength of material, and for fidelity of workmanship. On this point, I would strongly counsel ship-owners, in making contracts, not to pursue this system of mistaken economy, the result of which may be readily foreseen; but by a wiser liberality to secure the more perfect and satisfactory accomplishment of the object they have in view. No one, it may be here also remarked, can avoid observing and lamenting the low state, in this country, of what may be termed mercantile naval architecture, in which men of science meet with little or no encouragement to attempt improvements; and have become weary of a system which, for many years, has brought them no return. But let us hope for better things in iron ship-building; let us trust that both owners and builders will see that their interest lies—the former in procuring good sound vessels, and the latter in obtaining a price that will leave no excuse for imperfect work."

It would not be judicious to employ figures in estimating the cost of iron ships; the question can only be treated relatively, as the cost of both wood and iron vessels must always depend on the value of materials and the price of labour. But after a careful review of the whole subject, I may state my conviction, that iron and wooden ships bear nearly the same relative value for all classes—that iron ships of the same external dimensions, can be built for about 10 per cent. less than first class English-built wooden ships when coppered.

It must be always borne in mind, that builders of iron vessels cannot have the advantage, in one point, which is enjoyed by ship-carpenters; they cannot derive much profit from that which to the latter constitutes the cream of their business, namely, the *repairs*. What moderate profit can be realised, in these days of competition, must be derived mainly from the building of new vessels.

The first cost should also be estimated by a comparison of the carrying powers of the two kinds of vessels. This was stated to be in the proportion of 4 to 5 in small, and of 5 to 6 in large vessels. An iron vessel required to carry 250 tons, therefore equals, in the first cost, a wooden vessel that will carry only 200 tons; and an iron vessel required to carry 600 tons, will equal a wooden vessel built to carry only 500 tons. The advantage possessed by iron for steamers as respects stowage has before been noticed. The same reasoning also applies to the first cost.

8. Draft of Water.

Iron sailing-vessels may be built of any requisite depth and sharpness for holding on in a sea-way; but where a light draft is essential for a peculiar service, it may be attained to a greater extent by the use of that metal than by timber. This advantage, of course, arises from the weight of iron necessary in the construction of a vessel being much less than the weight of wood required for the same purpose. When iron vessels of very light draft are employed, means should be adopted—and many may be resorted to—to prevent them from drifting to leeward. The lee-boards of

Dutch vessels, navigating shallow waters, and the sliding keels in American pilot-boats and other vessels, are very efficient in this respect. A description of sliding keels is given in another place, and in Plate IX, figs. 1 and 2.

Iron vessels admit of this system with great readiness and security; and, when adopted, it has been proved to be highly successful.

Iron Vessels, as applied to Steam Navigation.

If the arguments adduced in favour of iron for shipbuilding be correct, we may date from the time of its introduction an era in the history of navigation, most important to the world at large, and more especially to this country. To steam navigation, its importance can scarcely be calculated. The machinery and fuel occupy a large portion of the vessel, aud the room for stowage is much curtailed. The weight and tremor of the engines shake and strain wooden vessels, and the machinery itself, until the repairs of both swallow up most of the profit that would otherwise be realised; and it is no trifling consideration, that in using iron for the hull, a finer form can be given, and consequently a much higher rate of speed, than can be attained in wooden vessels, while the lightness of iron vessels renders less necessary the full bow that is deemed an essential to the sea-worthiness of a timber-built ship. It may be added, that some of those nuisances which (though considered comparatively trifling by seamen) are exceedingly unpleasant to sensitive voyagers, are much reduced in iron vessels. The nauseous smell arising from bilge-water, worms, and

the eating away of the timber are instances of this kind, and their absence is very advantageous, especially in tropical climates.

It has long been felt to be desirable in steam navigation, that a greater degree of adaptation should exist between the vessel and the machinery. In wooden steamers, two interests have always to be reconciled. The ship-builder employs all those means which he conceives to be best calculated to strengthen his vessel, and too often clings to principles of construction, which, when applied to steamers, are ill-suited to the attainment of high speed. The engineer, generally very regardless of the requirements of the vessel, and having little sympathy with the ship-builder, thinks only of seeing his engines well accommodated, and working smoothly. If the vessel, when completed, goes well, both are exalted; if the reverse, neither is to blame. Unfortunately, a fair excuse may be made for this want of unity of design in the two departments. A wooden vessel, when she takes the ground, and, frequently, when she encounters heavy weather, becomes so much altered in shape, that were the engines so attached as to form "part and parcel" of the whole, they would be in danger of being broken down, or otherwise injured. The case is wholly different with iron vessels—in which, if properly built, there is no fear of twisting or settling. The engineer may, with perfect safety, firmly unite the vessel and the engine. Having to design both, and being responsible for the success of the whole, he will not allow one part to suffer for the benefit of the other, but take an interest in so combining both that they may mutually support each other. The various resources with

which his profession furnishes him, enable him to carry out one uniform and consistent plan. The lines, the trim, the draft of water, the strength, the power—all may be adapted to each other, and a degree of excellence be attained of which we can as yet form no adequate idea.

In steam vessels, the power to obtain great length is an evident desideratum, and we have not yet decided what are the limits to which this may be carried in iron ships; but it may be asserted with safety, that almost every increase in this direction has proved favourable as regards the speed, carrying qualities, and sea-worthiness of the vessel. The length for measurement is now frequently made to reach eight times the beam, and the depth, two-thirds the beam; and of ships built of these proportions, the commanders speak in great praise. Experience alone can show whether still greater length may be attained with advantage; I think it probable that this can be done with safety.

Let us again direct our unbiassed attention to wooden ships, and, viewing the subject dispassionately while we examine them, we shall be struck with surprise at the means employed in their construction, and the extraordinay complication of the frames, especially in large ships. It has been the work of ages to determine upon the several systems adopted, yet it is well known that all are still far from being efficient; and nothing proves more clearly the difficulty that surrounds the question, than the fact, that, to this day, with all the time, talent, and experience that have been brought to bear upon it, it is by no means decided which peculiar principle of building is the most advantageous; and it is within only the last few years that

a total revolution has been made in the science,—affording internal evidence that timber is *deficient* in many of the qualities requisite for ship-building. The force of custom is indeed strong; and had we throughout adopted iron alone as a material, it would have been naturally thought as impracticable to employ timber for such a purpose, as it was, a few years since, to use iron plates.

Shortly after the introduction of the screw propeller to ocean steam-ships, several attempts were made by the Americans to apply the screw to large timber-built vessels for the merchant service, and no less than four or five vessels came in succession from America to Liverpool. Though some of these were fine vessels, not one made a second voyage, in consequence of the unfavourable results commercially. Our iron vessels, however, are daily becoming more established in the very same trade.

IRON VESSELS, A NATIONAL QUESTION.

It is now everywhere admitted, that iron ship-building is of *national* interest; and, as such, it will be found to possess many claims to our attention.

To do full justice to this inquiry, it would be necessary to consider all the complicated questions relating to the timber duties, and the effect which the substitution of iron for wood in ship-building would have upon our colonies; but I confess myself unequal to this task, involving, as it does, many nice distinctions, and much tedious research. But, difficult as it may be to make correct calculations on this subject, and to show by figures the precise relative values of all the

points connected with it, no one will deny that it is of immense importance to this country, that her ships should be built in her own ports, with materials of her own production, and procured by the labour of her own population. And it must add greatly to the importance of this consideration, that the most suitable materials are abundantly found in the deep recesses of the earth, leaving the surface undisturbed, to be employed more exclusively in the growth of corn, instead of woods and forests. I would not be understood, by this argument, to admire the taste of our friends in America, who, after emerging from their dense and boundless forests, run into the opposite extreme; and see so much to be desired in their equally extensive prairies, without even a shrub or a twig to relieve the endless monotony of the scene. On the contrary, I feel all an Englishman's pride at the sight of a noble oak, which forms at once a shelter and an ornament to the land on which it grows. But how often are these swept away just as they attain their full growth and beauty, under the irresistible temptation presented by the great demand, and consequent high price of the timber!

At a meeting of the British Association, at Plymouth, Mr. Chatfield, of her Majesty's Dockyard there, read a paper on ship-building, and gave some interesting details respecting the *Hindostan*, seventy-eight gun ship, then on the point of being launched. He stated that,—

"To construct a ship of the tonnage of the *Hindostan* is a work of great labour, time, and expense. The value of labour alone is about 12,000*l.*; and it would take 154 men twelve months to build her. The value

of materials is about 60,000*l*., making the cost of the ship 72,000*l*. sterling. It would require 4200 loads of timber to build a ship of that description, and occupy seventy acres of ground eighty years for its growth.* The average durability of ships-of-war, employed in active service, has been calculated to be about thirteen years, when built of British oak, which happens to be precisely the period the *Hindostan* has been building, for she was commenced in August, 1828, and will be launched in August, 1841."

This case has been selected as coming from an unquestionable source. It proves, first—the great space of ground and the long time required to grow the timber of which they are built; and, secondly—their short average durability. Taking the facts stated as our data, but deducting one-fourth from the quantity of timber required for the *Hindostan*, as an allowance for the lighter scantling of one of our ordinary merchant ships, it would require the constant occupation of about 400,000 acres of land on which to grow the timber for the ships annually built in this country and in our colonies. So much of the timber thus employed as is grown in this country occupies a proportionate amount of land that would otherwise be appropriated to agricultural purposes; so much of it as is not grown here, takes our capital, to a certain extent, out of the country; but, worse than all, our people are deprived of profitable and extensive employment by the inducement to build ships in those countries where the material is most abundant. Notwithstanding the great sacrifice now being made in the

* Equal to 5600 acres for one year.

revenue of this country, by the reduction of duty on foreign timber, and the consequent decrease that will probably be made in the price, the foreigner will still have an advantage over us in having the material not only considerably cheaper, but at his own door, while our supply will necessarily be precarious.

State of Ship-building in England.

And here one cannot reflect on the state of English ship-building without perceiving that some great alteration is necessary in order to place it in its proper position. The price of new ships is too much reduced to allow room for profit, when labour and timber are so expensive as in this country; and I believe it is generally acknowledged that our ship-builders mainly depend for subsistence on repairs alone. But is it right, I would ask, that a large and respectable class of men whose profession should, from its importance, enable them to rank as high in wealth and station as they do in intellect—whose occupation requires the attainment of great scientific skill, should have their talents thus degraded—their energies thus cramped? Is it right that, in a land whose merchants are princes—in a land which claims the boundless ocean for its empire, the men who have spent their lives in so important and national an avocation should have no fair remuneration for their services? And where can we see any prospect of improvement while timber alone is employed, and while our population (already so dense) and the circumscribed limits of our soil for ever deprive us of the power to grow timber in sufficient quantity for our own ships?

But let iron become the material with which our ships are henceforth to be built, and the whole question assumes a widely different and a highly cheering aspect. Without being in any degree dependent on foreign countries, we should find an inexhaustible supply of more suitable and less perishable material for the whole of our national and mercantile marine in our own country; from this source our iron-masters would have a fresh and a steady demand for their iron, and an increased demand for labour, both at the mines and in our building yards, would be the immediate and invaluable result.

If I have not over-rated the superiority of iron in what I have advanced, it is clear that few foreign timber-built vessels could compete with our iron ships; and if other countries are driven to the use of iron, there can be no doubt where the advantage will lie. All nations yield the palm to England in the production and working of iron, and it will be long before we can be deprived of our superiority in this respect.

Obstructions to the Progress of Iron Ship-building.

I may here, again quote some remarks made in 1842:

"It will now probably be asked—'Why have not iron vessels become more general, if there be any truth in the opinions and assertions here brought forward; for, if such advantages really existed, would they not long since have become manifest to the most superficial observer?' I will not evade this enquiry. On the contrary, I gladly enter upon it, as I hope to explain the principal obstructions which have presented

themselves to the progress of ship-building in iron; and to satisfy those who would investigate the subject dispassionately, that the usual objections to the employment of that material are without foundation."

Time has now, to some extent, answered the question. Iron vessels since then *have* made great progress. Many objections then raised are shown to be without foundation, and are now silenced; others are much weakened, and are gradually giving way to the force of conviction.

Still it would be incorrect to say that there are no objections remaining, either real or imaginary; there are both; and I could not ask for the reader's confidence if I hesitated to expose them. The cause will be best advanced by showing the difficulties that lie in our way.

The Compass.

The assumed difficulty respecting the compass was a fair ground of objection. On this instrument the seaman relies for the safe navigation of his ship when out of sight of land, and it was natural that any derangement in its directive quality should be viewed with alarm. The inquiry, therefore, into the effect of iron-built ships upon the action of the compass is one of importance, and demands our special attention.

It was very early found by experiment that when an iron ship was upon some courses the compass needle deviated very considerably from the true magnetic meridian, while upon others there was little or no error; and that in apparently similar ships the compass was affected, not only to a different extent, but in quite an opposite manner. Thus, with the ships'

heads pointing in the same direction, in one the needle was deflected to the west, and in the other to the east of its true position. To meet this difficulty, Deviation Tables, as they were termed, were formed for the guidance of the seaman, in which the deflections of the needle from the magnetic meridian were inserted for each point of the compass, in the same way as had been found necessary for those wooden ships in which much iron was employed, either in construction or equipment.

Inconvenience frequently resulted from this plan, from the application of the correction being made in the wrong direction, and it was thought desirable to ascertain whether a correction similar to that which had been successfully used in some instances in wooden ships by Professor Barlow, could not be also applied to iron ones. In 1835, Captain Johnson, by direction of the Admiralty, undertook some experiments upon the iron steamer, *Garryowen*, in the Shannon, with this object, and also to ascertain the best position for the compass in iron ships. In a memoir on the subject, printed in the Philosophical Transactions, the following year, an unfavourable report on the possible correction by Barlow's plate was made. Deviation Tables for compasses placed in different positions were given, and it was suggested that the ship acted on an exterior compass much in the same manner as a large magnet. That an iron ship acts in the same manner upon an interior compass was definitively settled by the Astronomer Royal, Mr. Airy, two years after, by very careful experiments made upon the *Rainbow*, at Deptford, and the *Ironside*, at Liverpool. A paper, containing the particulars of the experiments,

and an elaborate mathematical investigation of the subject, appeared in the Transactions of the Royal Society for 1839. This paper showed that the magnetism of an iron ship, for any given geographical position, could be accurately represented by the action of a fixed permanent magnet, combined with the changing magnetism arising from the earth's induction on a horizontal bar of soft iron; and, consequently, that the effect of an iron ship upon her compass could easily be neutralised. In fact, the compasses of the *Rainbow* were so compensated in July, 1838, and the steering compass of the *Ironside* in a similar manner, two months afterwards.

Mr. Airy, with great liberality, also published a tentative method of adjusting the compass in an iron ship,* by which the calculations employed in the cases of the *Rainbow* and *Ironside* could be entirely dispensed with. This method has been extensively practised in all our great sea-ports ever since, and, in the hands of men who understood their business, with eminent success.

The operation may be shortly described as follows: —Having fully completed the equipments of the ship, especially as regards the iron-work, and having determined the exact position in which the compass is to be placed, take a point on the deck exactly under it; through this point describe two lines on the deck, one parallel to the keel, and the other at right angles to it. Provide two or three powerful magnets, about two feet long, and one or two boxes, about seven inches long, by three wide and three deep, and a quantity of small iron chain sufficient to fill them. The vessel,

* 4to. pamphlet, published separately, by Mr. Weale.

being in a wet dock, should be firmly held by four hawsers, with her head towards one of the cardinal points of the compass, as ascertained by a delicate azimuth compass placed on shore, and sufficiently far from the ship, or other masses of iron, to indicate correctly. Stand over the line on the deck which is parallel to the magnetic meridian, and observe whether the north end of the compass needle deviates from its correct position. If any deviation is observed, place one of the magnets on the deck, at right angles to the magnetic meridian, and with its centre immediately over the line marked upon the deck, the north, or marked end of the needle, being placed to the right hand, if the north end of the compass needle deviates to the right; or to the left hand, if the north end of the needle deviates in that direction. Move the magnet backwards and forwards on the line until the compass needle indicates correctly; and if one magnet is not sufficient for this purpose, use two, keeping them parallel to each other, and two or more inches apart. The ship's head must then be turned round 90°, so that the other line traced on the deck under the compass may be parallel with the magnetic meridian. Having ascertained, by the shore compass, that the ship is again steady on the cardinal point, observe, as before, whether any deviation exists, and correct it in the same manner. Next, place the ship with her head towards one of the four points, N.E., S.E., S.W., or N.W., as determined by the shore compass, and observe whether the compass indicates correctly; if not, proceed to use the chain boxes as follows:—First determine whether the boxes are to be placed fore-and-aft or athwartship; the latter being

the proper direction in ninety-nine cases out of one hundred; and whenever, the ship's head being N.E. or S.W., the north end of the needle deviates to the east; or, if her head be S.E. or N.W., the needle deviates towards the west. The chain box must be placed with its length in the horizontal direction, and with the centre of its end exactly opposite the centre of the compass card, and on the same level as the compass needle. Fill the box, if necessary, with chain, taking care to keep the centre of the chain at the same level as the needle; and if one chain box be not sufficient to make the compass point correctly, place a second box in the same manner on the opposite side, and put in chain, using similar precautions, until the four-point rhumb of the compass corresponds with the ship's head. When these corrections are made with great nicety the compass should be free from any practical error; but it is recommended that the ship should always be swung round afterwards, and the deviations, if any, noted on each, or on each alternate point of the compass, for the use of the captain in navigating the ship. The magnets employed should be of the best quality, and have been magnetised as long as possible previously, and kept in the interval before use with the marked end upwards.

Feeling satisfied that the views entertained by Mr. Airy were substantially correct, it became a matter of interesting inquiry with me to ascertain the proximate cause of the high degree of magnetic power which was developed in iron ships, and I commenced a series of experiments to see how far it might be due to the process of riveting. For I had, I believe in common with many others, long held the opinion that the

direction and quantity of a ship's magnetism were due to this, in combination with the polar direction of the ship's keel while upon the stocks.* My first experiments with this view were made on the *Alice*, built for the trustees of the Duke of Bridgewater's canal.

As iron vessels are generally built, it is very difficult to make correct observations to ascertain the effect of riveting. This operation proceeds at short intervals, and in different parts, as the plates are applied; and it would be almost impossible, should any alteration be observed in the compass, to ascertain whether it was caused by the plating or the riveting. Not having any premises near the water, where the *Alice* was built, we first erected her at our boiler yard, and afterwards re-erected her on a vacant piece of land at the water's edge, from which she could be launched in the usual way. It appeared to me that this presented an opportunity to ascertain the effect produced on a vessel by riveting; when, therefore, the plates had been put together at the water's edge, and before the riveting was commenced, I obtained a very delicate needle and made a few accurate observations as follows:—I drew a long line ahead of the vessel to the eastward, in the

* It will be in the recollection of many that the late Dr. Scoresby, at the meetings of the British Association, in 1854, claimed to be the first to direct attention to the influence which the earth's magnetism was likely to exert on the magnetic condition of the ship, as it concerned the direction of her keel while building. He also caused much alarm amongst shipowners by stating that great changes must be expected in the polarity of iron ships, and recommended, as it was supposed for the first time, that compasses should be raised on the masts or in some other manner above the deck.

These subjects were, however, not overlooked by iron ship-builders, and are all alluded to in my first work on iron ships, in 1842—and had been subject to experiment at that time. It has been reserved, however, for more advanced stages of the inquiry to ascertain correctly the causes which influence their magnetic condition, and the best means of obviating the difficulties that from the first were foreseen.

direction of the keel; and having selected a point at a considerable distance, where I could perceive no effect on the compass, I ascertained the direction in which the vessel pointed. I then measured one hundred yards from the vessel's stem, and there fixed the compass on the plane of the lower side of the keel. I could not here perceive any deviation; but as I moved forwards towards the vessel, the disturbance became very considerable. I carefully noted down all these results, and also made an observation under each quarter of the vessel. I now waited until the vessel was entirely riveted and nearly ready for launching, and then fixed the compass in the same places as before, and again observed the deviations. These I found to correspond most accurately with the first deviations, except in the last point, which was only one yard from the stem; but here the original support on which the compass rested had been removed, and I could not make any fair comparison. I think it possible, however, that the great number and size of the rivets which had been added since my first observations to the lower part of the stem, would have an effect on the compass independently of the hammering.

These experiments appear to countenance the idea that the polarity of the ship, as indicated by an external compass, is not affected to any extent by the riveting, if the ship lies with her head to the east or west; but subsequent experiments show that a compass placed in the inside of the ship is considerably affected by this operation. And also, that in vessels lying with their heads to the north or south, riveting, or, in fact, vibrations and concussions of any kind, tend to augment and fix, more or less completely,

into the vessel the induced magnetism due to her position while on the building slip.

Some persons have thought that as the individual plates of which the ship is composed have each some amount of magnetism, perhaps dependent on the direction in which they were rolled, or other accident attending their manufacture, the magnetism of the ship, as a whole, is made up by the combination of this sub-permanent magnetism belonging to her several parts. But a little investigation will show that the induced magnetism from the earth readily overcomes these original characteristics, even in the single plates, and that when they are placed together and subjected to the strains and concussions attendant on the riveting, this induced magnetism from the earth becomes so powerful, and is so strongly retained, as to completely neutralise their original tendencies, and to give a marked character to the whole ship, which she probably never afterwards entirely loses. That the earth should exert this influence was surmised at a very early period, and was suggested, as before stated, in the first edition of this work, though it was not until recently that it was fully demonstrated, and the apparently exceptional cases satisfactorily explained.

This inductive action of the earth on the iron of the ship may be well illustrated by its effect on an ordinary bar or rod of soft iron. If a rod of this kind be held with one end to the east or west of a delicate compass, the needle will be observed to deviate from its usual position, and to a greater or smaller extent according to the *direction* of the iron. The deviation will be at a maximum when the bar is held in the direction which would be assumed by a magnet freely

suspended by its centre of gravity. When the iron is held in a plane at right angles to this direction, it will be found to have no effect on the compass needle. As this action of the bar of iron depends entirely upon its position with respect to that of the freely suspended magnet, or in other words to its degree of coincidence with the direction of the earth's lines of magnetic force, it is reasonably concluded that its action is due to the induction of the earth. And this conclusion is strengthened by finding that the end of the bar which is nearest to the magnetic north acts as a north pole, and repels the north pole of the compass needle; and that the opposite end acts as a south pole, and attracts the north end of the needle. In any place, then, it is only necessary to know the direction of the earth's lines of force, that is, the direction of the dipping-needle, to understand the nature of the earth's inductive influence on the experimental bar in any given position.

If the reader has never tried this experimentally, or seen it tried by others, he is recommended to do so. A piece of rod-iron about a foot in length is very suitable; or even a large nail, if nothing else is at hand. He should observe also, that while the bar is held so as to produce a given deflection of the needle, if it be struck a smart blow with a hammer, or any hard substance, its susceptibility to the earth's inductive influence will be increased, and the needle will be deflected to a much greater extent. It must also be noticed that after the bar has been struck, it will retain a portion of the induced magnetism; that it will now affect the compass-needle when held in those positions in which previously it had no action; and that the

magnetism so held may be again discharged by cautiously striking the bar while it is held in the reverse position to that in which it was first struck.

We have seen that the experiments made by Mr. Airy on the *Rainbow* and *Ironside* led him to infer that the magnetism of an iron ship, from whatever cause it might arise, was of so permanent a character as to resemble, for any given geographical position, that of a steel magnet; and he gave reasons, which appeared satisfactory, for supposing that the changing portion of a ship's magnetism was so small that no serious difference would arise from change of latitude. In the concluding remarks to his paper of 1839 he observes:— "But it appears that one of the magnetic constants consists of two parts, which cannot be separated by experiments on the horizontal magnet at any one place; and that the effect of the impracticability of separating these parts will be to render the compass incorrect in one magnetic latitude, when it has been made correct in a different magnetic latitude (though there is good reason to think that the term on which the variation depends is so small that it may be neglected, except in the case of a ship sailing very near the magnetic pole)." On the other hand, a variety of experiments similar to those which we have described, on the inductive action of the earth on iron bars and plates, and particularly those exhibited and described by Dr. Scoresby in his numerous lectures on the subject, joined to reports which were occasionally heard of great magnetic changes having occurred in iron ships while at sea, led this gentleman and many others to suppose that only a small part of a ship's magnetism was really permanent, and that a change of hemisphere, or even that special circum-

stances in this hemisphere, might completely reverse a ship's magnetic character. The very interesting magnetic observations made by Sir James Ross during his voyage to the south, and discussed in the Philosophical Transactions by Colonel (now General) Sabine and Mr. Archibald Smith, also tended to confirm this idea.

Two or three most unfortunate shipwrecks among iron ships, which occurred about this time, were unhesitatingly attributed to compass errors by Dr. Scoresby and others, and public opinion on the subject of compensation by magnets became much divided. While one party placed implicit confidence in the Astronomer Royal, and the mode of compensation which he had originated, another party took the opposite extreme, and denounced all correction of the compass as likely to lead the unwary captain astray; as having been the cause of fatal casualties; and as tending to double compass errors on change of hemisphere.

The discussion of this question in various periodicals and newspapers, the papers on the subject brought before the members of the British Association at several of their meetings, induced practical men to ask for more facts, and for a careful and unbiassed inquiry into a subject of such great commercial and national importance. Ultimately a committee was formed at Liverpool, composed of ship-owners, ship-builders, underwriters, and others interested in the question, for the purpose of collecting information, and making the necessary experiments.* The investigations of this

* Mr. Towson, scientific examiner under the Marine Board in Liverpool, and the inventor of the well-known tables for facilitating "Great Circle Sailing," and myself were associated as honorary secretaries, and Mr. W.

committee have, it is believed, decided several important questions connected with the inquiry. The information thus obtained, so far as it has been embodied in the reports of the committee to the Board of Trade, will be the chief basis for the remainder of these observations. The report for 1856 is acknowledged to be a most important contribution to our knowledge of this intricate subject, and is stated by Mr. Airy to do more towards the settlement of disputed points than all which had hitherto been published.

I shall first describe the magnetism of an iron ship which is due to her position while building, and then advert to the changes to which it is liable; to the causes which modify its action while the ship is at sea; and to the remedies which have been, or may be, successfully applied.

The experiments which I am about to describe, and which are illustrated in Plate XIX. of the accompanying Atlas, were tried in the Sandon Graving Docks at Liverpool, and were suggested by the somewhat similar experiments of Dr. Scoresby on the *Eliza Harrison*, and those of Mr. Napier on the *Fiery Cross*. But they also give the deviations actually observed at regular stations opposite the whole side of each vessel; and in some of the examples, the result of similar experiments tried after the lapse of some months, so as to show the change which had taken place in the interval.

To describe one case in detail will sufficiently explain the whole; and I select for the purpose the ship *Sarah Palmer*, fig. 2, built at Warrington under

Rundell, late of Falmouth, was appointed paid secretary. It was to Messrs. Towson and Rundell that the committee were chiefly indebted for the satisfactory and important results which have sprung out of this investigation.

my inspection in 1854. Her head, when on the building-slip, was N. 76° E.; she will therefore exhibit the chief characteristics of ships built with the heads near the magnetic east. The correct magnetic bearing of the Graving Dock, fig. 1, having been ascertained to be N.N.E., an azimuth compass was placed at stations along the side of the dock, opposite the ship, selected so that the iron posts, &c., might have no perceptible action on the needle. The direction of the dock was ascertained at each station, and the difference between these observations, and the correct bearing, was recorded as the deviation due to the influence of the ship. These stations are indicated on the diagrams by dots placed at the intersection of the horizontal and vertical lines on the shear draught of the ship, and also by the dots A, B, C, &c., in the transverse section in fig. 1. The lines of no deviation are then inserted, so as to divide the east from the west deviations. The dark lines are those obtained after her first voyage to Calcutta, in July, 1856; and the fainter lines are from observations made after her second voyage, in April, 1857.

Fig. 3 shows the lines of no deviation of the *Bœotia*, likewise on two occasions. The strong lines were obtained while she was first fitting for sea, April, 1856; and the faint lines in the September of the same year, after the ship had made two or three voyages to the Mediterranean. They well illustrate the magnetic character of ships built with their heads a little to the west of south.

In the same manner, fig. 4, the *City of Washington*, will illustrate that of ships built with their head to the north, or near it. The dark lines were obtained in January, 1856, and the light lines in November, 1856.

Figs. 5 and 6 are introduced as showing a considerable contrast to each other; the former, the *Barcelona*, was built with her head approaching to S.W., and the latter, the *Borysthene*, not far from N.E. No. 7, the *Sarah Sands*, shows a ship built head to east, after having been many years in active service, and after traversing both hemispheres. Fig. 8 represents the *Royal Charter;* her magnetic lines will be seen to resemble those for the *City of Washington*, and also illustrate the change which took place while she was being repaired in the Graving Dock.

When compasses in iron ships are placed at some distance from individual masses of iron, such as rudder-head and stern-post, iron bulk heads, funnels, &c., they show great uniformity in the character of their deviations, so that it may be told with considerable accuracy what the nature of the deviation will be, from knowing how the ship was built; or, seeing the tables of deviation for compasses so situated, at once suggests the approximate direction of the building-slip. The following table will indicate with sufficient accuracy for our present purpose the characteristics to which we have alluded:—

Approximate Magnetic direction of Ship's Head while Building.	Maximum Easterly deviations are observed when Ship's Head by compass is near	Maximum Westerly deviations are observed when Ship's Head by compass is near
North.	West.	East.
South.	East.	West.
East.	North.	South.
West.	South.	North.
N.E.	N.W.	S.E.
S.W.	S.E.	N.W.
N.W.	S.W.	N.E.
S.E.	N.E.	S.W.

If the compasses have been compensated, and a change in the ship's magnetism takes place, the deviations will then usually be in the opposite direction to those above stated.

That these changes do take place no longer admits of doubt, but they are believed to be of comparatively small amount after the ship has made her first voyage, or if precautions are taken while the ship is fitting out to keep her in a position as nearly as possible opposite to the one in which she was built. The greatest amount of change is always shown by those steering compasses which are placed in the ordinary position near the rudder head, and stern post, and especially on change of hemisphere. Compasses which are placed more towards the centre of the ship, and which are elevated some five feet or more above the deck, do not usually show much change; neither do mast compasses, when care is taken in selecting their position.

From what has been previously remarked, it will be seen that these changes arise from two causes—decrease in the ship's original magnetism, or that which depends on her position when building, which change is rapid at first, and afterwards extremely slow—and a change arising from the earth's inductive influence on alteration of geographical position.

A short description of the laws which govern the second cause of change will conclude this necessarily brief account of the magnetism of iron ships, and its effect on the compass.

When referring to the earth's inductive magnetism a few pages back, we stated that it produces its maximum effect on a bar of iron when that bar is held

in the direction assumed by the dipping needle. In practice it becomes necessary to resolve this force into two, acting at right angles to each other, namely, the vertical and horizontal directions, at the place of observation. Where the needle takes the horizontal direction—as near the equator—the whole of the earth's magnetic force is horizontal and none vertical; where the dipping needle becomes vertical, as in high north or south latitudes, the whole of the force becomes vertical; there is none horizontal. In the first case, vertical iron has no effect on the compass through the earth's induction; in the second case, horizontal iron has no effect. In intermediate geographical positions, the forces in these two directions will vary as the sine and cosine of the angle of the dip. For example, in Great Britain, where the needle dips about 70° from the horizon, the horizontal induction will be in the proportion of cosine of 70°, and the vertical as the sine of 70°, and so for any other dip. We see, then, as regards vertical iron, that it has no influence upon the compass from induction near the equator, but that its induced magnetism increases, as the sine of the dip, as we approach either pole of the earth. The reason for this separation of the earth's induction into its vertical and horizontal components, or in other words into the effect of vertical and horizontal soft iron, will be understood when it is stated that the compass deviations which they produce differ widely in their character. The deviations from horizontal induction have four maxima and four minima; its effect is therefore *quadrantal*. Vertical induction produces only two maxima and two minima; its effect is therefore *polar*, and it, with the *polar magnetism* hammered into the

ship while building, produces the two constants alluded to in the extract from Mr. Airy's essay. The former is compensated by the chain boxes, and for reasons which need not be stated here, produces the same effect on the compass needle of a *compensated compass* in all parts of the world; this compensation, therefore, when once made, requires no further alteration. The latter varies in *amount* as the sine of the dip, and also in its *action* on the horizontal compass needle in proportion to the cosine of the dip; consequently, the *deviation* produced by the earth's induction on vertical iron will vary as the tangent of the dip. Hence it is that compasses placed near masses of vertical iron, such as steering compasses placed near the stern-post and rudder-head, or a standard compass if placed near a bulkhead, change so much in their deviations on change of hemisphere; and hence the necessity for giving the captain the means of regulating the distance of the compensating magnets so as to counterbalance such changes. A convenient apparatus for effecting this end will now be described.

But though these changes occur, it is not the less true that the magnetism of an iron ship can always be completely neutralised by the use of permanent magnets and chain boxes or soft-iron correctors; and we trust it is evident that the former, instead of being fixed on the deck, must be made movable at the will of the captain. Mr. Airy proposed a mode of doing this some time ago, also Mr. John Gray of Liverpool, who is well known for his skill as a practical compass adjuster. Mr. Gray's plan has been patented, and is reported to act very satisfactorily. It affords any captain who will attend to the subject the means of

keeping his compasses quite correct under all ordinary circumstances, and in all parts of the world. A sketch of this apparatus is appended, Plate XX., figs. 2, 3, 4. Its distinguishing feature is that the captain, by merely turning a screw, 5, 5, fig. 3, can bring the compensating magnets nearer, or place them further from the compass. He is enabled also to take away or add magnets, 4, 4, to the frames 3, 3, fig. 3, as may be required, and with great facility, the only precautions being that when at sea the magnets must never be moved unless the ship be first turned so as to bring them at right angles to the magnetic meridian of the place. Thus, if at the position of the ship the *variation* of the compass is 10° east, and the transverse magnet or magnets are supposed to require to be moved, the ship's head must be placed by azimuth observations or by a compass, whose deviations, if any, are correctly known, 10° east of the *true meridian* of the place. Then the screw of the transverse frame must be turned until the compass to which it is attached shows ship's head to be magnetic north. The ship's head must then be turned to correct magnetic east or west, ascertained as before, and the screw attached to the fore-and-aft frame be screwed up or down until the compass is perfectly adjusted. The chief thing to be kept in mind by the captain using this valuable apparatus is that he should never be tempted to move a magnet until he first turns his ship, so as to bring the magnet at right angles with the magnetic meridian of the place; as, until he does this, he is unable to say whether it requires to be moved or not. The chain boxes are shown by *c*, *c*, fig. 4; fig. 1, and the references attached, will illustrate the details of Gray's improved floating compass, perhaps

the best and steadiest instrument which has yet been constructed for withstanding the tremors incidental to screw steamers.

This notice of the effect of iron ships on the compass, though only intended to be of a general character, would not be complete unless I alluded to another cause of deviation, namely, that which arises from heeling in some ships. The information on this head, which has been hitherto collected, is very incomplete. There is, however, reason to suppose that it affects to the greatest extent ships that are built with their heads to the north or the south. I am informed by Mr. Rundell, the Secretary to the Compass Committee, who has paid more attention to this subject than perhaps any one else, that it will probably be found that on ships built head to north the effect of heeling is always to draw the north end of the compass needle to the weather side, the deviations reaching their maxima when the ship's head is north or south by compass, and showing little or no effect when the ship's head by compass is east or west. In ships built head to south, the north end of the needle will be drawn to the lee side, the maxima and minima deviations corresponding with those observed in ships built with their heads to the north. Mr. Rundell is also of opinion that these deviations from heeling may be completely compensated.*

It is impossible to enter into all the details of this

* The subject of heeling, as it affects the compass, has been for some time noticed. Captain Masters, who commanded a small barque designed by me in 1844, called the *Josephine*, and the first iron sailing ship, I believe, ever built in the Clyde, wrote a most interesting paper upon his observations on the compasses, and obtained by it a medal from the Institution of Civil Engineers. His remarks are well deserving attention.

inquiry without far exceeding the limits which have been assigned to this work. The reader who desires to know more is referred to the various papers on the subject by Flinders, Barlow, Sabine, Airy, Smith, Johnson, Walker, &c., and to the reports of the Liverpool Compass Committee. After a careful revision of the whole question I think I shall be justified in stating that with our present knowledge on the subject of the magnetism of iron ships, and the modes of compensating it, it must now be considered as practically settled; that the men of science have done their part of the work, and that henceforward it becomes more a question of COMPETENCY IN THE COMMANDER, AND OF EQUIPMENT ON THE PART OF THE OWNER.

Lightning.

As the employment of iron ships extends, they will frequently be, and doubtless are now, exposed to circumstances in which great danger might be apprehended from violent electrical discharges, and in which most disastrous results have taken place; such, for instance, as the following. In June last, the American revenue cutter, *Fancy*, was struck by lightning, which shivered the topgallant mast to atoms, and shattered the topmast and foregaff in pieces, ripped up the bolts, and, continuing down the foremast, took a large piece out of it twenty-two feet long, and struck all the watch on deck senseless. The decks were literally covered with fragments of the masts. And in another case, which occurred in a French ship of the line, when struck with lightning on the mainmast, a small wire rope attached to the mast, and leading to the water, entirely

disappeared, portions of it being scattered in all directions; several men were hurt, and some damage done to the ship: or in the case of the emigrant ship, *Helvetia*, which, though provided with a conductor of the ordinary kind, was struck by lightning. A portion of the electrical discharge, notwithstanding the presence of the conductor, passed through the ship itself, and killed an emigrant asleep in his berth.

Sir W. Snow Harris, in a paper printed in the "Nautical Magazine" of November in this year, reasoning on these and similar cases, shows that there is no absolute security in what are called lightning-rods, which are used under the supposition that a small rod of metal is at all times sufficient to transmit great electrical discharges.

In the same paper Sir William proceeds—"It was for a long time assumed that such a line of metal, commonly called a lightning-rod or conductor, had the power of attracting to itself the matter of lightning, and causing it to pass harmlessly into the earth—a notion which gave rise, as was likely it should, to much violent controversy as to the amount of security such pointed rods could ensure, as compared with the quantity of atmospheric electricity which, by their supposed attraction, might be drawn down from the ship or building to which they were applied. An extensive generalization and a large induction of facts, however, served at an early period to assure me that such disputes were altogether fallacious, and based upon an assumption hypothetically false. Metallic substances are in themselves really indifferent to the electrical discharge, and are no more attractive of lightning than any other species of common matter:

that lightning, in certain cases, falls on metallic substances, rather than other bodies, arises solely from the circumstance of their offering less resistance to its progress when occupying a certain position in space. Lightning, however, does not so fall if a still less resisting path be open to it, even although that path be through worse conducting matter, in which case the electrical discharge is found to avoid as it were metallic substances and pass them by altogether:—that the only effectual security against lightning is the application of capacious electrical conductors, not partially but generally applied, by which a ship or building is brought into that little resisting state it would assume as regards lightning as if it were metallic throughout, or as nearly as may be; in this case the electrical discharge could not enter upon any circuit of which the conducting system did not form a part, and thus by finding unlimited room of expansion in all directions in its course to the earth, to which by a law of nature it is determined, the explosive action would become transformed as it were into a comparatively quiescent or current action free from any attendant destructive force;—this is, in fact, the great general principle upon which the permanently fixed conductors I proposed so many years since to be employed in the Royal Navy is based."

It will be at once seen that the iron ship fulfils the conditions here required. It is, as regards the hull, "metallic throughout;" it is "the application of capacious electrical conductors not partially but generally applied;" and experience has shown that a ship may be enveloped in a blaze of electric fire, accompanied by terrific explosions, without damage to hull or masts.

Instances are recorded of iron ships being struck under these circumstances, but in all cases, as far as I know, without doing mischief.

There may be conditions, however, under which the masts of iron ships may suffer; the conducting power of wire rigging may be broken, and cause an interruption in the current; it may therefore be well to use precautions to make a continuous metallic connection down the masts and to the shell of the vessel.

Sir W. Snow Harris, in a letter to me on this subject, says:—"I can have no hesitation in believing that a metallic ship of any kind would be safe from lightning—that if the ship, masts, sails, and rigging were all metallic, and of a continuous character, such a condition would obtain as to render the whole indestructible by lightning, at least for such atmospheric discharges as have come within human experience. In fact, explosive electrical discharge is the result of the electrical agency forcing a path through resisting matter; on the contrary, when it traverses little resisting matter, such as the metals, then the explosive power of action vanishes; it is, as it were, transformed into *current action* as near as may be. An iron ship, with iron rigging, should be secure from lightning. There is, however, no general principle not liable to certain contingencies: the masts are, I suppose, of wood; the rigging, twisted wire rope—the worst form of lightning conductor you could have, as we see by the many cases in which such wires are knocked to pieces by lightning; and although certainly in a large number of cases we might expect to find discharges of lightning well disposed of in the case of an iron ship with metallic rigging, yet it might not always be so as

concerns the masts or such parts of the hull (suppose wood beams or deck) as are not metallic; as to the shell of the hull, there can be no doubt about that. I am therefore of opinion that it would be *always* judicious to complete the conducting power of the masts to the keelson, as done in the Navy. But, certainly, in any case an iron ship, with metallic rigging, would be infinitely more safe from lightning than an ordinary ship."

The danger to be dreaded from the known derangement of the compass—which at first sight involved one of the most serious objections—and all apprehensions from the effect of lightning being thus far satisfactorily set at rest, a great advance has been made, and we might have felt that further advocacy was unnecessary; but, unhappily, to many persons connected with shipping, and whose ideas have long been wedded to wood, as the exclusively applicable material for that purpose, the novelty alone of the principle still appears in their minds to justify the vague opinions and surmises of its inefficiency, which, from the force of prejudice, are magnified into obstacles to its general adoption. Even men of considerable experience still question whether iron vessels will finally prevail, and, as if anxious to obtain the confirmation of their opinions, search out or imagine objections, seizing upon every defect in those first constructed, and holding them up as satisfactory proofs of the doubtful nature of the principle, without giving themselves the trouble to think of the improvements which have been made, and that others may be made. Time having shown, at least to a great extent, that one of their first objections — the supposed rapid

corrosion of iron in water—was no longer tenable, they began to lay great stress on the tendency which iron has to become foul, when long immersed in salt water, but it is not difficult to show that this evil, though still unconquered, has been much overrated.

Besides, means will doubtless ere long be successfully employed for this purpose. The opposition thus shown to iron vessels is not only to be regarded as injurious, because retarding a scientific improvement, but as deterring shipowners from adopting the principle, and causing them still to invest large sums in the construction of timber vessels, which, before they are launched, have in reality lost much of their value by the rapid improvements in iron vessels.

Iron ship-builders themselves are not always free from blame, as having by their imprudence injured the cause, or impeded its progress by using materials of inadequate strength, by carelessness in its scientific application, or by imperfect workmanship, frequently the results of accepting contracts that will not remunerate them for the construction of strong and well-built ships. In their eagerness to obtain business, they have allowed themselves to be guided and controlled by those who have orders to give. This should be firmly guarded against, as leading to the construction of vessels unfit for service, and placing the principle of iron ships in jeopardy. Iron vessels were at first generally adapted to situations in which wood vessels were objectionable or inapplicable, a light draft of water being the advantage sought; and it frequently happened that to obtain this, every other advantage was sacrificed. To ensure great displacement, the models

were generally too full. They would consequently neither sail fast (particularly on a wind), nor steer well; and they were sometimes almost without keels, or any other means of preventing them from drifting to leeward, a defect rendering them nearly unmanageable in a heavy sea. All these objections, which may be entirely obviated by the adoption of proper models, the employment of material of sufficient strength, and fidelity of workmanship, were seized upon by the opponents of iron vessels, and arrayed against them, as if they were inseparable from the principle.

Underwriters * for several years occupied a position

* The following remarks were written in my pamphlet of 1842, and we can now observe the effect produced by a more favourable feeling, on the part of underwriters, to be such as I foresaw :—

"I have before alluded to the powerful influence possessed by underwriters in causing the public to encourage or reject improvements ; but in the same proportion as their unfavourable opinion has impeded, and still may for a time impede, the building of iron ships, so will their approval and willingness to reduce the premiums of insurance on such vessels cause them to come more rapidly into general use. I sincerely hope that this desirable change in the sentiments of underwriters is not far distant, and that they will render unnecessary what has long been contemplated by the iron masters, and other men interested in iron vessels,—namely, the establishment of a Marine Insurance Company that will insure iron vessels at moderate premiums."

The following observations were also written at the same time, and are rapidly approaching fulfilment :—

"In contemplating improvements in steam vessels, we are not to confine ourselves to a few advantages that may be given to lines already established; but, embracing a wider range, suppose them constructed of materials that will remain firm and wholesome for many years in any climate, and that may without much danger track through seas beset with hidden rocks and treacherous coral reefs.

* * * * *

"The engines being reduced in size and weight; the speed and stowage much increased; the consumption of fuel lessened to one-third of the present average, what part of the globe may not then have its steamers, what sources of employment does not the prospect hold forth to this country, and what immeasurable advantages may not thereby arise to our widely extended colonies ? When we consider the results of such improvements, we are lost in conjecture of the amazing extent to which our resources may be applied. We have steam vessels now plying regularly to North and South America ; we have them in the Pacific, in the Mediterranean, in the Red

in this question which justly brought upon them severe reflections from those who were struggling to establish the new system. They appeared to lend a willing ear to the unfounded objections which were raised, and while under the force of conviction, iron *steam* vessels were insured at lower rates than wooden vessels, iron sailing vessels found no favour with them, and even where owners were willing to pay a higher rate for their *vessels*, shippers of goods were deterred from supplying them with cargo. This course was for a long time fatal to their progress, and it was not till very lately that the inconsistency of it was fully apparent; but, it is with much satisfaction that we are now made to feel that a different course is pursued. I shall have occasion to refer to this subject in another place.

Sea, and in the Indian Ocean, as far as Calcutta, and even China; and these are only the main navigable highways, from which numerous small lines may be expected to branch, filling up every intermediate space, affording a continuous and profitable intercourse with countries the most remote, and thus diffusing amongst tribes the most barbarous or benighted, the blessings of civilised life.

"Our steamers may probably ere long do more to keep open and extend our trade with China, by plying along the shores and up the rivers of that country, than can ever be accomplished by the sound of our guns. South Australia—the antipodes to our own country, and in itself a continent—also presents itself with even higher claims to our consideration as the mother country; and it is not too much to assume that there the general adoption of the English language, and English iron-built steamers, will concurrently be the promoters of commerce and civilisation. All these redeeming advantages, and many more, may be achieved by British enterprise. But, knowing, as I do, from long experience, the precarious and deteriorated condition of timber-built steam vessels, when long exposed to such service, even improved as they now are—knowing the constant necessity for repairs, without the means of effecting them, and the comparative want of room for stowage, I feel satisfied that it is left to the employment of iron, and all the improvements that will follow in its train, to carry out those desirable objects."

Fouling.

The fact that iron vessels become coated in tropical climates with shells and weeds has operated considerably against them, but both the effect and the ultimate consequences are greatly exaggerated. That the objection exists cannot be denied, and it constitutes at present the most annoying circumstance connected with iron ships.

It has been found in tropical climates that the small shell-fish called by naturalists the *balanus*, probably from its tendency to adhere to whales; also, the common barnacle, when in a pulpy state, collect on every floating object, and if time is given, increase to a large size; being the production, however, of salt water, they cannot live in fresh water, so that vessels which enter fresh water rivers after a sea voyage, soon lose their unwelcome companions: thus, a vessel leaving this country for Calcutta, if a fast sailer, will arrive there before the animalculæ can have grown to a size sufficient to cause any obstruction, and starting again in a clean state, will arrive home in good condition; and I have frequently seen the same result after a quick passage, where no such purification has taken place; but when the vessel is detained for some time in hot climates it becomes very foul, and the speed is much retarded, though no other bad effect arises.

Numberless chemical combinations have been suggested for the abatement of this nuisance, but I should not be stating the honest conviction of my own mind if I claimed for any the much-desired result.

To find some substitute for the copper sheathing of wooden ships, and to apply it to iron ships, has been

the favourite idea which has long prevailed, and coatings have therefore been prepared, in which the oxide of copper has been a large ingredient; but probably this application has been adopted from a mistaken view of the effect of copper in preserving a ship from fouling —if it is, as some suppose, a mechanical and not a chemical action that keeps copper clean, no varnish or coating can have the same effect. Copper oxidises in salt water, and, unlike other metals, the oxide does not adhere to it, and thus the shell-fish and weeds which fasten to it are thrown off as the successive layers of oxide leave the surface of the plates.

Sir Humphry Davy thought he had discovered a principle that would be a great boon to shipowners. It was known that the oxidation of copper would be much retarded by producing a galvanic action on the plates; this was done by putting bars of other metals, such as zinc or iron, in contact with the copper, which being mutually acted upon by the acid in the water, produced the desired effect. The shipowner had the prospect of having his copper endure the friction of the water double, if not treble, the usual period; but what was the result,—the vessel came home as foul as if she had never been coppered; from which it is inferred that without oxidation even coppered vessels have the same evil to contend with as iron ships.

For the present, therefore, we can only await some remedy that, no doubt, will be found, and in the meantime care, and such precautions as are at hand, should be adopted. Amongst these may be suggested any application that will make a smooth surface, which the friction of the water will keep clean longer than a rough surface. I have seen the application of a thin

coat of a strongly adhesive cement, put on the plates with a kind of trowel; this fills up all the inequalities of the iron, and the paint which covers it forms a much smoother surface than when applied direct to the plates.

Copper Sheathing for Iron Ships.

This question has occupied the attention of many inquirers into a remedy for the fouling of iron ships. To place copper in immediate contact with the iron is obviously opposed to all known chemical laws; and many suggestions have therefore been made to sheath the vessel with wood, and then apply the copper; but to do this seemed to require that the timber should be bolted to the plates, and thus occasion a large number of holes in the hull, a course which is quite inadmissible.

I offer, without comment, a plan for obviating this evil—a plan for which I obtained a patent a few years since, and of which I annex a descriptive drawing.

First, I propose to reduce the amount of inside frame-work, and to apply a certain number of frames externally, thus producing the same strength with the same weight of iron. The external frames are something like common angle iron, but having the projecting flanche, of a wedge form, as shown at *a*, fig. 1, Plate XVIII.

Secondly—I should prepare a quantity of plank, *b b*, about three inches thick, cut into short lengths, having the ends slightly bevelled; these are placed between each frame, beginning at the keel, and laid parallel to it. A number of short wooden wedges, *c c*, are also prepared, and as each short plank is applied, it is

fixed in its place by the wedge; a good coat of pitch should be applied, under and between each plank, and when all has been dubbed or planed to a level surface, another good coat of pitch should be applied, thus forming a compact, immovable, and impervious sheathing. This sheathing need not be carried above the water line, where the upper edge should be protected by a bar of angle-iron, applied horizontally, as at A, fig. 2.

Thirdly—I propose to nail to this foundation a planking of an inch and a-half in thickness, as is usual in sheathing wooden vessels. Fig. 2 shows the section of a vessel thus sheathed, and fig. 3 the side of the vessel; A is the bare plate, B is the inner plank and wedge, C the wood sheathing nailed to the inner planking, and D, the copper sheathing.

Fourthly—The application of the copper requires no description, as it will be attached by nails, as in wooden vessels—observing, however, that it is kept two or three inches from any exposed piece of iron.

Lastly—I may mention that I have applied this framing and sheathing to single plates, and find that with ordinary care it forms such a solid mass that it cannot be removed without being cut out; and also, from the most delicate tests, I have found that several cheap descriptions of coating are such perfect non-conductors, that no injury whatever can arise to the iron from the proximity to the copper.

Builders have given me estimates of the cost of this application, and I find that it is much less than would at first be imagined.

I leave those who are most interested in the success of projects for the protection of iron vessels in warm

climates to consider how far this plan is worthy a trial, and how far it will overcome the greatest remaining objection to iron ships.

Iron Ships for the Government Service.

There are two classes of vessels employed by Government,—those which are armed, and intended for fighting ships, and those which are used as transports, or in the postal service, under contract with Government. As regards the former, much has been said and written on the question of the employment of iron in their construction, and upon this point I am willing to confess, that the opinion I at first formed as to its fitness for this class of vessel, subsequent experience has led me to withdraw. In two material points iron vessels are deficient. The injury they would sustain from shot is probably much greater than in timber-built ships; and as no effectual remedy has yet been found against fouling, their employment on foreign stations, where there are no means of cleaning them every six months, is undesirable.

But for these reasons, iron ships would be as eminently serviceable for men-of-war, and as superior to timber-built ships, as they are found to be in the merchant marine. Great strength, increased internal capacity, durability, and comparative lightness, are all qualities which will be found in iron ships, and the value of which would be as important in the navy as in merchant shipping; add to this, their well-known power to resist the concussion of their own guns, and their peculiar suitability as steamers, which are the

only vessels that will soon be found on the lists of our national marine.

Upon the important question of their power to sustain the enemy's fire, great discussions have taken place; and I must state my conviction, that the result of careful experiments, and especially of those conducted by Captain (now Commodore) Chads, in the *Excellent*, at Portsmouth, were anything but encouraging to the hopes entertained, that iron ships would supersede wooden ships in the navy.

Careful and fair experiments were tried against butts of various kinds, made of iron in combination with timber and other materials, and on iron alone. The results were, however, unfavourable; as, contrary to expectation, the splinters proved very destructive, and in some cases the seams and plates were much torn. I imagine that the damage caused by a shot would be the greatest on the opposite side of the ship from which it enters, in those cases where it passes through both sides; on the side that the shot enters, the plates being supported by the ribs at the back, would not materially lose their form; but on the opposite side, the plates might be forced away from the ribs and serious rents be made, sufficient, if near the water, to sink the ship.

During the late war with Russia, attempts were made to form floating batteries* cased with iron above the water-mark, the plates being 4½ inches in thickness, and merely bolted to the sides of a timber hull. There was no expectation that these plates would add to the strength of the vessel, but the contrary; they were

* These were said to be the invention of the Emperor of the French.

simply intended to act as a coat of mail to a large floating battery, while under the fire of land batteries. One only of these vessels was thus engaged, but then not under circumstances that gave any good proof of their efficiency, as the fire was distant and not very heavy. They would, however, no doubt sustain a heavy fire, and be useful for attacks upon forts on land. But as the power of gunnery is still further developed, even these plates may form but a doubtful protection; evidence of this was given by a shot fired at one of them on the shore near Liverpool, from the great wrought-iron gun made at the Mersey forge, which resulted in the complete destruction of the plate.

With regard to the second class of Government vessels, viz., transports, or vessels employed in the postal service, the case is very different, and has lately undergone a great change.

At the first establishment of mail-steamers receiving a subsidy from Government, it was thought an excellent stroke of policy to engage that the vessels should be at the disposal of the Admiralty for war purposes, when required. We were then without a steam fleet, and such fine vessels might be eminently serviceable in towing the ships of the line, or even to carry large guns. The Admiralty, having decided that iron ships were not adapted for war purposes, passed a resolution that no iron vessels should be built to carry the mails; supposing that being of iron would destroy their usefulness, when required for the navy. One large Company is said to have resisted this regulation, and the Government, after consideration, withdrew it. It was evident that the ships of the navy should be themselves steamers; that, under any circumstances,

steam-vessels, as they were then built for the Post-office service, with the machinery far above the water-line, were quite unfit for close action; their highest qualification was speed, to enable them to escape from pursuit of an enemy, rather than to contend with him. The successful application of the screw in the navy, where the machinery can be kept below the water-line, has finally decided all questions upon this subject, and probably no steamers for private companies will in future be built of timber.

THE "LEVIATHAN."

In the early part of this work, when sketching the history of iron ship-building, the *Leviathan* was alluded to as forming the most remarkable undertaking ever projected in connection with this subject; it is now necessary to enter more fully into details, and to describe the Plates which illustrate her construction and general arrangements.

The design of this vessel originated with Mr. Brunel, and she is now building at the ship-yard of Messrs. J. S. Russell and Co., of Millwall.

In a work of such magnitude many heads have been employed, and while Messrs. Brunel and J. S. Russell have produced the great outlines of the structure, they have been ably seconded by Mr. Yates, the Secretary of the Company, and by Messrs. Hepworth and Dickson, the shipwright and engineer, under whose management the practical departments have been conducted.

The hull and the engines for the paddle-wheels were undertaken by Messrs. J. S. Russell and Co., and the

engines for the screw were contracted for by the eminent firm of Messrs. James Watt and Co.

She was commenced in the year 1853, and is now (1857) nearly completed, the machinery and boilers being on board.

This description is written under some disadvantage, as the vessel is not yet afloat, and some of the details are not completed, and while this work is in the press the process of launching will probably take place.

The leading points in her construction are, however, sufficiently developed to make the following account useful to practical men, and a sufficient record of a work having considerable public, almost national interest.

As steam vessels have increased in size, so have their power to overcome the difficulties of long distances been increased also; and the nearer have we approached to the successful accomplishment of rapid steam communication with our most distant possessions. Notwithstanding, however, the rapid strides made in the improvement of steam navigation, success, commercially, has not attended our efforts to reach Australia, India, or China direct from this country. One great reason for this is, that our steamers, large as they are, cannot carry sufficient coals for the entire voyage, without occupying all the space required for cargo, and so overloading them as to reduce their speed to a low average. The *Leviathan* was designed to meet these disadvantages, and thus originated the construction of the largest ship the world ever saw.

The lines and the outer shell seem to have been first determined upon, and then followed a considera-

tion of that internal system of cross-bracing and longitudinal trussing that would, with the least weight of iron preserve her outward form.

It was determined to give strength and security to the outer shell by making the portion under the water-lines, and a few feet above it, double or cellular; that the internal plating should serve the two-fold purpose of giving direct strength to the ship, and protection in the event of the outer plates being damaged. The space between these plates is about thirty-four inches, and in it are placed, in a longitudinal direction, rows of plates, the intervals being regulated by the strain which each portion will have to sustain, the bottom of the ship having a greater number of these girder frames than the sides. The cellular system is applied to the upper deck, and corresponds, in this respect, with the tubular bridges on the Holyhead Railway and elsewhere. The ship thus becomes a monstrous iron girder, capable of spanning with safety from ridge to ridge of the ocean's waves.

But while labouring at sea, a ship has to encounter strains which tend, in a lateral direction, to derange the correct form of the hull; and to meet these in the *Leviathan*, an elaborate system of transverse and longitudinal bulkheads is introduced, and she is thus divided into numerous water-tight compartments, so arranged as to form the required spaces for engines, boilers, coals, cargo, and passengers. In a ship of this magnitude, such divisions form little or no obstruction to the proper stowage of the ship. It will be seen on the plan that two longitudinal bulkheads run about half the length of the ship, forming the sides of the boiler and engine compartments, and extending to the upper

deck. While these add strength in a longitudinal direction, they serve also to unite in one body the transverse supports derived from the deck-beams and the transverse bulkheads.

When the strength of iron plates, placed on their edge is considered, it is impossible to conceive any system which can give to the general structure greater strength with the same weight of iron.

The plates by which all these parts are formed, are, of course, united in the usual manner by angle iron. The plates for the hull are uniformly $\frac{3}{4}$ of an inch thick; and those for the bulkheads, $\frac{1}{2}$ an inch. The angle iron generally used in her construction is $4\frac{1}{2} \times 4\frac{1}{2} \times \frac{1}{2}$, but in the gunwale it is $8 \times 3\frac{1}{2} \times \frac{1}{2}$.

The angle iron ribs usually employed in iron ships, are, in this case, wholly omitted; the engineer depending for the required strength of the hull on the vertical position of the plates, placed in every direction at right angles to the strains. Experience and time alone can decide whether this deviation is advantageous or otherwise. It is probable that the want of angle iron ribs may be felt, when the vessel receives concussions from hard bodies, such as floating ice, or from other vessels; or even when pressing, with its ponderous weight, against piers, or other stationary objects. In the spaces between each longitudinal frame, a large surface of plates is exposed. This objection, if real, has, however, no reference to the general strength of the ship, which appears to be amply sufficient.

A few particulars of the dimensions, construction, and arrangement of the vessel may be interesting, and are therefore added; though, in doing so, I am deviating from the strict object of this work.

The length of the *Leviathan* between the perpendiculars is 680 feet, and on the upper deck, 692 feet; the breadth of the hull, 83 feet; and including paddle-boxes and their fenders, 118 feet—equalling the width of Portland Place, one of the broadest streets in London, or in England; the depth of the hull is 60 feet; the weight of iron in the hull is 7000 or 8000 tons; the launching-weight, 10,000 to 12,000 tons; and the weight of the whole ship when fully laden, with every contemplated article and person on board, not less than 25,000 tons! With this load she will draw 30 feet of water. There are thirty-five ribs or webs running longitudinally from stem to stern, in the space between the inner and outer shells.

There is no external keel, and the bottom is quite flat for about half the breadth.

The number of plates is said to be about 10,000; and the number of rivets about 3,000,000.

The interior of the ship is thus arranged: Running crosswise are ten or twelve iron water-tight bulkheads, as before described, extending the entire height to the upper deck, with no openings below the lower deck; except in the coal bunkers, where water-tight doors, which can be closed at a short notice, are fitted; the ship is thus cut off into ten or more compartments, generally about sixty feet long, any one of which might be filled with water up to the level of the lower deck, without flooding any of the others—a matter of great importance in the event of shipwreck. Five of the compartments near the centre of the ship form five complete hotels for passengers; each comprising upper and lower saloons, bedrooms, bar, offices, &c.; and each cut off from all the others by the iron bulkheads.

The arrangements are intended for 800 first-class passengers, 2000 second-class, and 1200 third-class and soldiers. The crew and engineers, 400 in number, will be accommodated near the two ends of the vessel. The upper deck is flush fore and aft, except sky-lights and ventilating openings, thus presenting a promenade nearly *an eighth of a mile* in length. The arrangements are planned with an amount of room and comfort for each passenger never attempted in other ships: the upper saloons being twelve feet in height, and the lower nearly fourteen.

The means of propulsion are the combination of paddle, screw, and sails. The paddle-wheels are fifty-six feet in diameter, larger than the circus or arena at Astley's amphitheatre, with float-boards about thirteen feet long. They are driven by engines with four cylinders, the largest ever made on the oscillating principle; the cylinders have a diameter of seventy-four inches, and fourteen feet stroke. The screw-propeller is twenty-four feet in diameter, with four fans or vanes, and a shaft one hundred and sixty feet long, and are driven by four cylinders eighty-four inches in diameter, with four feet stroke. Each cylinder for the screw-engines required thirty-four tons of metal in the casting.

There are ten boilers and one hundred furnaces. It is supposed that sails will not be needed in the ordinary state of the weather; but to take advantage of a very brisk wind in a favourable direction, and to assist in steadying and steering, there are six masts carrying 6500 square yards of canvas—five of these masts are iron, and one of wood. To aid the sailors and engineers in working the ship, there are auxiliary steam-

engines, from which power may be "laid on" for hoisting sails, heaving anchors, pumping, &c. There will be ten anchors, 800 fathoms of chain-cable, and numerous capstans and warps. The plans include an electric telegraph to communicate orders to various parts of the ship—especially from the commander to the engineer, the look-out man, and the helmsman. Gas will be made on board, to light the various parts of the ship. In order to leave no precautions for safety unprovided, there will be boats enough to contain all the passengers and crew: two of them being screw-steamers ninety feet long, hung on davits abaft the paddle-boxes.

The great length of this vessel has rendered necessary the adoption of a new plan for launching. In ordinary circumstances, a ship is built on a sloping ground or slip, with a descent of about one foot in eighteen towards the water-side; but in this instance the vessel is built on a level, broadside towards the river. For launching, two timber platforms have been constructed, extending from the ship's position to low-water mark; each platform eighty feet in width, and having a slope towards the water of one in twelve, rests on a deep bed of concrete; on the platforms rails are laid for the cradles to move upon. Two cradles, one between the midship and the head, the other between the midship and the stern, are prepared. The launching will take place at low water, and the rising tide will then float her off.

The following references will explain the Plates XXII., XXIII., and XXIV., containing different views of the *Leviathan*.

First.—Plate XXII. represents a longitudinal section

of the vessel, with a half-breadth plan and the lines of the ship.—1. The main transverse bulkheads; 2. Partial bulkheads beneath lower deck; 3. Funnels from the five pairs of boilers; 4. Screw-engines; 5. Paddle-engines; 6. Screw-engine boilers; 7. Paddle-engine boilers; 8. Cargo space; 9. Cargo and horse space; 10. Officers' and crew's berths; 11. Capstans, chains, anchors, &c.; 12. Passengers' saloons; 13. Coal-bunkers; 14. Auxiliary engine-room; 15. Rudder; 16. Screw-propeller; 17. Forecastle; 18. Tunnel for screw-shaft; 19. Paddle-box.

Plate XXIII. is a section of the ship at the broadest point amidships.—1. Upper saloon; 2. Cabins; 3. Cabins, baths, &c.; 4. Lower saloon; 5. Tunnels; 6. Coals; 7. Boilers. This section also shows the cellular structure of the double skin round the lower part of the hull, and of the upper deck.

Plate XXIV. is a section on a smaller scale, of the portion which contains the engines for working the paddle-wheels, and, therefore, shows the size and position of the paddle-boxes. The large chamber, 1, is the space for the engines, which have been already described; 2. The paddle-boxes; 3. The paddle-shafts; 4. The brackets on the ship's sides which carry the shafts; 5. The top and bottom paddle-floats; 6. The coal-bunkers; 7. The fore and aft engine-beds; 8. Stair-cases in the paddle-boxes, communicating from the main to the lower deck.

Such is a slight description of this wonderful vessel. It will give but a faint idea of her imposing size; a personal inspection can alone enable the mind to grasp the reality. Who does not wish complete success to this daring enterprise!!

Lloyds' Register of British and Foreign Shipping.

This Register, and consequently the Committee and officers who conduct it, exert a powerful influence on the shipping of this country, and, as might be expected, are frequently the subject of severe criticism, sometimes, perhaps, justly, as using the almost irresponsible power with which they are invested with a sterner tenacity, and more unbending sway, than is consistent, —on the one side, with the intelligence which they may sometimes fetter; and on the other, with the well-known mistakes, frequently made by those to whom they must look for information. In no case has this been so strikingly exhibited as in the struggles with which iron ship-builders have had to contend. In the early stages of this great national work, engineers were the men who first saw the advantage of iron as a material for ship-building, and they were necessarily the first who led to the practical development of the system. Their mortification will be easily understood, when it is recollected who were placed in judgment over their work; it was, in fact, the very class of men who, from early training, from imbibed prejudices, or from self-interest, would be disposed to view with dislike a system, upon the merits of which the greater number were unqualified to give correct opinions. Amongst these were to be found not a few of Lloyds' surveyors; and this will be felt from the fact, that some very inferior specimens of iron ship-building have been produced under the recommendation of a "special survey." But the case is now much altered for the better.

It will be admitted that the duties of this establishment, if firmly administered, must expose the executive to many unjust reflections, in consequence of having to deal with cases where their decision carries with it an influence on the value of property so extensive as that of our merchant shipping.

These embarrassments are greatly increased by over-legislation; that this is impolitic is every day seen, by the rapid advances which are being made in practical science, setting all previous experience and all established rules at defiance. I freely admit the difficulty that hence arises; lay down rules, and you cramp our energies; leave us unfettered, and property and life are endangered.

We, therefore, only claim intelligent and enlightened co-operation. Let it be admitted that we, who were the originators of the system, who have struggled on through a sea of difficulties, who have shown by the result that we were not mistaken, ought to be judges of what we have so long studied, and there is little doubt that benefits will accrue to all parties.

Underwriters now discuss the question with a clear knowledge of its merits, and of its remaining disadvantages. The Committee for Lloyds' Register take much pains to legislate wisely and liberally upon it, and in their officers may be recognised increased intelligence and candour in dealing with it. Under these circumstances, I cannot think that we shall advance our cause by continuing to exclaim against those who, though they may not satisfy us in every particular, no longer look upon our work with indifference or distrust, but seem most willing to promote it, by making it a subject of careful consideration, and take much

pains to frame Regulations that will not cramp the efforts of builders and ship-owners.

A copy of the last-revised Regulations issued by Lloyds' Committee is annexed, and I may notice one great improvement over their former rules, in the increased space given to the frames. There can be no objection to a uniform space for all classes, as the scantling of the iron can at all times be regulated to correspond with the difference in the size of the ship.

A rather striking instance of the force of custom, however, is given in these Regulations. I have before drawn attention to this subject, but a few additional remarks may here be useful. In a wooden ship, durability mainly depends on the nature of the timber, and of the fastenings, due consideration being had to the scantling. A three-inch plank in the smaller ship is as durable as a six-inch plank in the larger ship, and in some cases, more so. A uniform classification for *years* is, therefore, consistent; and that the terms should be short, is also in accordance with sound experience; but in iron ships the case is altered. The durability must, to a great degree, depend upon the thickness of the plates, and it is probable that, in practice, this will increase in a far greater degree than is due to the mere increase of thickness. But if we refer to the table for the thickness of plates, we shall find that the small vessel, with a plate $\frac{6}{16}$ of an inch in thickness, has the same *term of years* as a larger vessel of $\frac{14}{16}$ in thickness; and it is not improbable that twice twelve years will have expired before any perceptible alteration in our largest and best-managed ships will be observable. The matter can, however, be dealt with, when some

of our large ships, built under these Regulations, have attained a greater age.

I have before given reasons for objecting to a uniform thickness of the plates and of the angle-iron throughout the length of the vessel, especially in fine ships, where the increased weight at the ends is undesirable. I think, also, that as additional care is observed in jointing the plates, some of the riveting may be dispensed with. It is only necessary to take notice of the plates of a large ship, with the holes punched, and countersunk ready for riveting; and the impression is unavoidable, that they are unnecessarily weakened by the process. And lastly, I would again draw attention to the fact of the excellent condition of many of our early built vessels, plated and framed with twenty and thirty per cent. less weight of iron than is now thought necessary,—a fact worthy of consideration in the construction of regulations for scantling.

With these remarks, I feel that the Rules, as they now stand, give an assurance that the system has met with impartial justice at the hands of those who have been engaged in framing them.

RULES FOR THE BUILDING OF SEA-GOING IRON SHIPS OF ALL DESCRIPTIONS, WHETHER SAILING OR NAVIGATED BY STEAM.

1. The whole of the iron to be of good malleable quality, and the manufacturer's name to be stated in the report of survey, the workmanship to be well executed, and to be submitted to the closest inspection before coating or painting, and any brittle or inferior article to be rejected. It is not intended to prevent the coating of the plates inside in the way of the frames.

2. The keel, stem, stern, and propeller posts are to be scarphed or welded together at discretion, and to be in size according to Table G; if scarphed, the length of scarphs to be regulated in the proportion of eight times the thickness given in the table for keels, and the stern posts, and after end of keel, for screw-propelled vessels, to be double the thickness of, or twice the sectional area of, the adjoining length of keel (but the siding in no case to be less than the thickness of the keel), and to be tapered fair into the adjoining length of keel. Where the garboard strakes are thicker than required by the rules, and extend to the bottom of the keel, the thickness of the keel may be proportionably reduced, but such reduction not to exceed one-third of the requisitions of the Rule. Where the keel and keelsons are made of several thicknesses of plates, the plates that form the keel to be in thickness, taken together, the same as is required for a solid keel, as per Table G; and the butts of the

several plates of which the keel is formed to be carefully shifted from each other, and from the butts of the garboard strakes, which in all cases must also be shifted, so as not to be opposite each other.

3. The spacing and dimensions of the ribs or frames, to be as per Table G, and the ribs or frames in as great lengths as possible, and to be fitted close on to the upper edge of the keel, and in all cases to extend to the gunwale, and wherever butted, to have not less than four feet lengths of corresponding angle-iron fitted back to back to cover and support the butts and receive the plating. And if welded together, the welds to be perfect, and the shifts not to be less than four feet.

4. The floor plates to be in thickness as per Table G, and to extend beyond the bilge keelsons, and to be in depth at middle line not less than one inch for every foot of the vessel's depth, measured from the top of upper or spar deck beams to top of floor plate, and not to be less in depth at the bilge keelsons than the moulding of the frame. A floor plate to be fitted and riveted to every frame, and at the ends of the vessel the floor plates to be worked across the middle line, so as to support and unite the sides of the vessel efficiently to each other.

5. Reversed angle-iron on frames to be in size as per Table G. All vessels, of whatever size, to have reversed angle-iron riveted to every frame and floor plate across the middle line to the height of upper part of bilges, and to have double reversed angle-iron in way of all keelsons; and in addition all vessels of 300 tons and upwards to have reversed angle-iron extended from bilges to the upper deck beam stringer

on alternate frames, and vessels of 800 tons and upwards to have reversed angle-iron extended on every frame from bilges to lower deck or hold beam stringer, if the vessel has two decks or tiers of beams, and to the height of middle deck beam stringer if the vessel has three decks or tiers of beams; the rivets for securing the reversed angle-iron to the frames and floor plates to be in diameter equal to those specified in the table for the outside plating, and not to exceed six times their own diameter apart.

6. The middle line keelsons,* if of single plate, to be of the same thickness as the floor plates, and if standing above the floor plates to be well fitted and riveted to the same, and a reversed angle-iron to be fitted on each side, both on the top and the bottom, extending all fore-and-aft, the lower angle-irons to be secured to the double reversed angle-irons on the top of floors. If box keelsons be adopted, the plating to be of the thickness as per Table G, and in either case to be two-thirds of the depth of floor plates.

If intercostal middle line keelsons be adopted, they are to be of the same thickness as the floor plates, and riveted to vertical angle-irons on all floor plates at each end, the plates to extend from upper edge of keel to above the upper edge of floor plates, sufficiently high to be riveted between the double angle-irons extending all fore-and-aft, of the dimensions given in the Table G, and the said double angle irons of keelson are to be riveted to double angle-irons on top of all floor plates.

* In all cases the keelsons, and, *where practicable*, the shelf-pieces and stringers, are to be carried fore-and-aft, without being cut off at the bulkheads, the latter being made water-tight around them; and where such parts of the ship are necessarily separated, they are to be efficiently connected, to the satisfaction of the surveyor.

7. The bilge keelsons to be fitted and secured in an efficient manner, extending all fore-and-aft, and placed at lower turn of bilges, according to the form of the bottom. In ships of 1000 tons and upwards, an intercostal keelson to be fitted on each side, fore-and-aft as far as practicable, about midway between the middle line keelson and the bilge keelson, with double angle-iron riveted on the top of floor plates. All vessels of 500 tons and upwards to have fitted between the bilge keelsons and the hold beams, at the upper part of the turn of bilge, strong angle-irons, as stringers, extending all fore-and-aft, riveted back to back to the reversed irons on the frames, the size of them not to be less than those used for the middle line keelson.

8. All plates to be well fitted and secured to the ribs and each other, the butts to be closely fitted, and to be united by lining pieces or strips of not less than the same thickness as the plates, and of sufficient breadth for riveting, as described hereafter. No butts of outside plating to be nearer each other than one space of frames, nor to be nearer to a scarph of keel than that distance.

The space between the outside plating and the frames, to have solid filling pieces closely fitted in one length, of the same breadth as the frames.

9. In the outside plating, stringer plates upon beams, angle-iron on stringer plates, and flat of deck of raised quarter-decks, a reduction of one-fifth from the thickness required by the Table G for such parts in the range of the upper deck in ships with two decks will be allowed.

In the outside plating, stringer plates upon beams,

angle-iron on stringer plates, and flat of deck of full poops and top-gallant forecastles, a reduction of one-fourth from the thickness required by the Table G for such parts in the range of the upper deck in ships with two decks will be allowed, and for the beams of full poops and top-gallant forecastles a reduction of one-fifth will be allowed. The united lengths of poop and forecastle not to exceed three-fifths of the entire length of the upper deck.

In the scantlings of beams, plating, flat of deck, stringer plates, and angle-iron on stringers to upper (or spar deck) in vessels with three decks, viz., upper, middle, and lower deck, a reduction of one-sixth from the dimensions given for such parts in the range of upper deck in ships with two decks will be allowed.

10. For the spacing of beams the depth of hold is measured amidship from the top of the floor plates to the top of the upper deck beams in vessels with two decks, and to the top of the middle deck beams in vessels with three decks.

The beams to be of the dimensions as per Table G, and to be made of "bulb" or any other approved iron plates, with reversed angle-iron riveted to the plates, the beams to be well and efficiently connected or riveted to the corresponding frames at the sides of the vessel, with bracket ends or knee plates of thickness equal to the beams, and in length, as per Table G, also to the stringer plates, the beams of each deck to be over each other, and pillared where practicable.

Upper deck beams in vessels with one or two tiers of beams, and the upper (or spar deck) and middle deck beams in vessels with three tiers of beams, to be fastened to alternate frames.

Vessels of twelve feet and under thirteen feet depth of hold, or where the gross register tonnage exceeds 200 tons, shall be required to have as many hold beams as may be practicable or convenient, fastened to, at least, every eighth frame.

Vessels of thirteen feet depth and under fifteen feet, to have hold beams fastened to every fourth frame.

Vessels of fifteen feet depth and under eighteen feet, to have hold or lower deck beams fastened to every second and fourth frame, alternately.

Vessels of eighteen feet depth and under twenty-three feet, to have hold or lower deck beams fastened to every alternate frame.

All vessels having two decks, and exceeding twenty-three feet in depth to the upper side of upper deck beams, and in vessels with three decks, viz., upper (or spar), middle, and lower deck, and exceeding twenty-three feet in depth to upper side of middle deck beams, such vessels to have orlop beams fastened to every sixth frame.

Where a deviation from the foregoing rules as applying to beams takes place in way of engine-rooms or hatchways, or where no deck is intended to be laid, and the above-named spaces would materially interfere with the stowage of cargo, and where partial or entire bulkheads with horizontal shelves and stringers between them, or larger beams are substituted for ordinary beams in wider spaces, a sketch with all particulars must be submitted, through the resident surveyor, for the Committee's consideration. The middle deck to be a perfect deck laid and caulked.

11. The rivets to be of the best quality, and to be in diameter as per Table G; the rivet holes to be

regularly and equally spaced and carefully punched opposite each other in the laps and lining pieces or strips, to be countersunk all through the outer plating; the rivets not to be nearer to the butts or edges of the plating, lining pieces to butts, or of any angle-iron, than a space not less than their own diameter, and not to be further apart from centre to centre than four times their diameter, or nearer than three times their diameter, and to be spaced through the frames and outside plating a distance equal to eight times their diameter apart. When riveted up they are completely to fill the holes, and their points or outer ends are to be round or convex, and not to be below the surface of the plating through which they are riveted. All edges or horizontal joints of outside plating to be double riveted in vessels intended for the twelve years' grade of 700 tons and upwards, and from keel to the height of upper part of bilges, all fore-and-aft, in vessels intended for the nine years' grade, and for twelve years' grade under 700 tons. The stem, stern post, keel, edges of garboard strakes and sheer strakes, and butts of outside plating, and butts of floor plates, breasthooks, transoms, and plates of beams, also butts of keelsons, stringers, shelf-plates, and all other longitudinal ties, to be double riveted in all vessels. The overlaps of plating, where double riveting is required, not to be less in breadth than five times the diameter of the rivets; and where single riveting is admitted, the overlaps to be not less in breadth than three times the diameter of the rivets. If double riveting be adopted where single riveting is allowed by the Rules, the diameter of the rivets may be reduced one-sixteenth of an inch below that prescribed by the Rules, pro-

vided that in no case the diameter be reduced below five-eighths of an inch. The butts and edges of outside plating to be truly fitted, carefully caulked, and made water-tight.

12. In addition to the engine-room bulkheads of steamers, all vessels to have two water-tight bulkheads, built at a reasonable distance from the ends, to extend from the keel, and outside plating to the upper deck in vessels with two decks, and to the middle deck in vessels with three decks (otherwise called "tonnage deck"); but it shall not be required to extend the aftermost bulkhead to this height if it be continued above the load water-line, and be connected to a water-tight platform or deck of iron, extending from its upper part entirely round the after part of the vessel, thus enclosing the lower after-body in a water-tight tank. If a screw shaft passes through a bulkhead, it is to be made water-tight at the bulkhead. All plating of bulkheads to be of the thickness prescribed in Table G, and to be closely fitted between two frames or ribs at each side of the vessel, and strongly riveted through them, or if attached only to one frame, then to have brackets or knee-plates riveted horizontally against the side plating of the vessel and to the bulkheads, fore-side, and aftside alternately, near the middle of the outside plates, to be strongly riveted thereto. Lining pieces between these frames and outside plating in way of bulkheads are to be plates extending in one piece from the foreside of the frame afore the bulkhead frames to the aftside of the frame abaft the bulkhead frames; also the bulkheads to be supported vertically by angle-irons of the dimensions given in the Table G, which are not to exceed two feet six inches apart, the

whole to be efficiently connected and riveted together and to the corresponding floors, beams of the several decks, and the frames or ribs. The whole of the bulk-heads to be caulked and made thoroughly water-tight.

13. The wood ceiling or lining of all vessels from 100 to 3000 tons to be from one-and-a-half inch to three inches in thickness, in proportion to the tonnage, and to be so fastened to the reversed angle-irons or frames that it may be easily removed for survey and painting.

14. The waterways and planksheers, if of wood, not to be inferior in quality of material to that which is prescribed in Table A for vessels built of wood of the same grade. The flat of upper deck to be fastened by screw bolts, put through from the upper side, and to have nuts at the under side of the angle-iron of the beams; where the planks exceed six inches in width, two bolts in each plank in every beam, one of which may be a short screw bolt. The waterways to be fastened with screw bolts, with nuts at under side of stringer plates.

15. All vessels to have stringer plates upon the ends of each tier of beams, to be not less in breadth and thickness than the dimensions given in Table G, the said stringer plates to be fitted home and riveted to the outside plating at all upper decks, and at the middle deck in vessels having three decks, with angle-iron of the dimensions given in the Table; and the stringer plates of the middle deck of ships with three decks to have an additional angle-iron extending all fore-and-aft inside of the frames, and riveted to the reverse angle-iron on the frames. All vessels to have upon each

tier of beams a tie-plate* each side the hatchways, of the dimensions given in Table G, extending all fore-and-aft throughout, and well riveted to the upper sides of all the beams, deck-hooks, and transoms. Also to have plates, where practicable, of the same dimensions, extending diagonally from side to side, riveted to the upper side of beams and stringer plates.

16. The main piece of rudder to be made of the best hammered iron, and so arranged as to ship and unship, where practicable, without docking, and the main piece to be in size according to the Table G.

17. Vessels intended for either the twelve, nine, or six years' grade to be surveyed at least five times, in the following order, viz.;—

On the several parts of the frame, when in place, and before the plating is wrought.

On the plating during the progress of riveting.

When the beams are in and fastened, and before the decks are laid.

Again when the ship is complete, and before the plating is finally coated.

And lastly, after the ship is launched.

All vessels to be subject to occasional or annual survey when practicable, and every third year to be specially surveyed in dry dock or laid on blocks, with both surfaces of outside plating exposed; and whenever the engines or the boilers of iron steam-ships are taken out, the vessel shall be submitted to a particular and special survey.

* Upon hold beams, where no deck is intended to be laid, or where such tie-plates would materially interrupt stowage of cargo, an angle-iron, of the dimensions given in the Table G, for "Angle-Iron on Beam Stringers," will be admitted in lieu thereof, placed at the middle line, extending all fore-and-aft throughout where practicable, and well riveted to all beams, deck-hooks, and transoms.

Continuation of Iron Ships to the Character A.

18. If, on the termination of the period of original designation, or if at any subsequent period, not exceeding one-half the number of years assigned originally, or on restoration, an owner shall wish to have his ship remain or be replaced on the letter A, he is to send a written notice thereof to the Secretary, and the Committee shall then direct a special survey, as follows, to be held by not less than two competent persons, to be appointed by the Committee, one of them to be a surveyor, the exclusive servant of the Society:

Survey.

The vessel to be placed on high blocks, in a dry dock, or upon ways, and proper stages to be made, so that the rivets and plates of keel, and flat of bottom, may be thoroughly examined; the whole of the ceiling or lining inside to be entirely removed; coal-bunkers of steam vessels to be cleared, so as to expose the whole of the frames, stringers, hooks, floor-plates, keelsons, engine and boiler bearers, ends of beams, water-tight bulkheads, rivets, and inner surface of the plating,—to view; the hold to be cleared; all oxidation to be removed by being cut or beaten off the several parts above-named; also, from the outside plating, rivets, keel, stem, stern-post, and rudder, so as to completely lay bare all the surfaces of iron; the plank-sheers and waterways, if of wood, to be scraped bright: and when the vessel is so prepared, the surveyors are to examine and report the condition and thickness of all the parts of iron above-named; also the condition

of the planksheers, waterways, flat of decks, and their fastenings; and upon the owner consenting to remove and replace with proper materials, equal in substance and quality to the original construction, such parts as may be found defective, or less than three-fourths of the required substance by rule, such vessel, upon the repairs and efficiency being reported to the Committee, may be continued on the letter A for a term of years not exceeding one-half the number of years assigned originally; or, on restoration, subject to occasional or annual survey, when practicable. The period of continuation will, upon all occasions, commence from the time the ship may have gone off the letter A, without regard to the date when the survey for this purpose may be held.

Restoration of Iron Ships to the Character A.

19. If, *at any age of a vessel*, an owner be desirous to have his ship restored, such restoration, on his application to the committee, and consenting to the special survey hereinafter described, to be held by two surveyors, one of whom shall be an exclusive servant of the Society, and performing the repairs thereby found requisite, will be granted for a period not exceeding two-thirds of the time originally assigned, the same to be calculated from the date of such repairs.

Survey and Requisites for Restoration.

The vessel to be placed on high blocks, in a dry dock, or upon ways, and proper stages to be made, so that the rivets and plates of keel, and flat of bottom, may be thoroughly examined; the whole of the ceiling

4	1200 and under 1500
4	1500 and under 2000

deck hooks, and
ships are to be
at each tier of
is required for
diameter of the
e iron carlings;
d for the main
The mast-holes

r as per Table;
from the faying
outer plating;
s and edges of

originally, subject to occasional survey.

Iron ships, which have been restored under the for

mined; the whole of the ceiling

or lining inside to be entirely removed; coal bunkers of steam vessels to be cleared; the boilers to be taken out, and also the engines (unless it shall be shown by previous survey that the removal is unnecessary), so as to expose the whole of the frames, stringers, hooks, floor plates, keelsons, engine and boiler bearers, ends of beams, water-tight bulkheads, rivets, and inner surface of the plating,—to view; the hold to be cleared; all oxidation to be removed, by being cut or beaten off the several parts above-named; also, from the outside plating, rivets, keel, stem, sternpost, and rudder, so as to completely lay bare all the surfaces of iron; the planksheers and waterways, if of wood, to be entirely removed, and also the flat of upper deck, except under special circumstances, to be sanctioned by the Committee in each case: and when the vessel is so prepared, the surveyors are to examine and report the condition and thickness of all the parts of iron above-named; also, the condition of the beams and their fastenings. And, upon the owner consenting to remove such parts as may be found defective, or objected to, or less in thickness than hereinafter admitted for repairing such vessel, and replace them with proper materials equal in quality and substance to that required in the Table G for the nine years' grade in those originally classed 12 A, and equal in quality and substance to that required in the Table G, for the six years' grade in vessels originally classed 9 A or 6 A, such vessel, upon the repairs and efficiency being reported to the committee, may be restored to the letter A, for a term of years not exceeding two-thirds the number of years assigned originally, subject to occasional survey.

Iron ships, which have been restored under the fore-

going rule, shall be entitled to continuation thereon, subject to the same conditions of survey and examination as are prescribed for ships proposed to be continued at the expiration of the period first assigned to them; but, in like manner, the term of such extended continuance to be limited to a period not exceeding one-half the number of years for which the ships may respectively have been restored, without reference to the period originally assigned to them.

20. On the expiration of the terms assigned to ships classed A, they will be liable to lapse (like ships built of wood).

21. One year will be added to the character of all ships of the A class, built under a roof which shall project at each end beyond the length, and on each side beyond the breadth, a quantity equal to one-half the breadth of the vessel.

22. Vessels not surveyed while building, will be classed A from year to year only, but for a period not exceeding six years.

Iron Ships already Classed A 1.

Iron ships built prior to the promulgation of the Rules will be allowed to remain in the Register Book classed A 1 from year to year, *subject to annual survey,* until the expiration of six years from their date of build, and then be examined to determine the period to which they may be entitled under the Rules; and if, on such examination, it shall be found the ships are entitled to the nine or twelve years' grade, it will be in the option of the owners either to adopt such period respectively, or continue the vessel A 1 from year to

year, as above, until the expiration of the extended period; but if it shall be found that the term of years for which a vessel would have been entitled to remain on the A character has expired, she will be classed Æ, if entitled thereto, unless specially surveyed for continuation or for restoration.

The rules for the building of iron ships having been now for some time before the public, and the principles upon which they are framed having been found generally to work satisfactorily; and the committee having very carefully revised the several Regulations, especially in respect to the thickness of the plating and the extension of double riveting, beg respectfully to urge upon the builders of iron ships the necessity of a close approximation to the Rules, and a conformity to the Table of Dimensions, so as to justify the Committee in granting the character A for the respective periods for which the ships are built.

By order of the Committee,

GEORGE B. SEYFANG,

Secretary.

No. 2, *White Lion Court, Cornhill.*
London, 21*st May,* 1857.

SURVEYOR'S REPORT.

FORM FOR THE ORIGINAL SURVEY.

No. ——. Survey held at ——. Date ——, 18 — on the ——. Master ——. Tonnage—Gross ——. Engine Room ——. Register ——.. Built at ——. When built ——. By whom built ——. Owners ——. Port belonging to ——. Destined Voyage ——. If Surveyed Afloat or in Dry Dock ——.

	Feet.	Inches.
Length aloft		
Extreme Breadth		
Depth from top of Upper Deck Beam to top of Floor . .		

	Horse.	No.
Power of Engines		

	Inches in Ship.	Inches Required per Rule.
Distance of Frames or Ribs from moulding edge to moulding edge, all fore-and-aft . . .		

	In Ship.			Required per Rule.		
	Inches	Inches	16ths.	Inches	Inches	16ths.
Floors, Size of Angle-Iron and No. — at bottom of Floor plate						
,, depth and thickness of Floor Plate at mid line						
,, Ditto at bilge keelson						
,, Size of Reversed Angle-Iron, and No. — at top of Floor Plate						
Frames, Size of Angle-Iron, single or double . .						
,, ,, Reversed Iron; if to every frame or every —— frame						
Beams, Deck (No. —) double Angle-Iron or Bulb-Iron with double Angle-Iron on top						
,, ,, depth and thickness of Plate amidships						
,, ,, double or single Angle-Iron, on lower edge						
,, ,, average space between						
,, ,, if wood (No. —) sided and moulded						
,, Hold, or Lower Deck (No. —) double Angle-Iron or Bulb-Iron with double Angle-Iron on top						
,, ,, depth and thickness of Plate amidships						
,, ,, double or single Angle-Iron, on lower edge						
,, ,, average space between						
,, ,, if wood (No. —) sided and moulded						

		In Ship.			Required per Rule.		
		Inches	Inches	16ths.	Inches	Inches	16ths.
Beams, Paddle, wood, sided and moulded, or if iron, size of Plate							
,, Engine ,, ,, ,,							
Keelson, wood, sided and moulded, Iron size of Plate, if Box, give sketch and dimensions							
,, Side or Bilge							
,, Number							
Stem, if Bar Iron, moulding and thickness							
,, if Plate Iron, breadth and thickness							
Stern-post, if Bar Iron, moulding and thickness							
,, if Plate Iron, breadth and thickness							
Keel, if Bar Iron, depth and thickness							
,, if Plate Iron, breadth and thickness							
	Description of Iron.						
Garboard Plates, thickness							
From Garboard to upper part of Bilge							
From upper part of Bilge to Sheerstrakes							
Sheerstrakes							
Breadth and thickness of Butt Straps to outside plating							
	Material.						
Planksheers							
Gunwale Plate or Stringer on ends of Upper Deck Beams							
Angle-Iron on ditto							
Waterway							
Deck							
Ceiling in Hold							
Ceiling betwixt Decks.							
Beam Clamps							
,, Shelf							
,, Stringer Plates on ends of hold or lower deck Beams							
Ceiling between Decks							
Stringer or Tie Plates outside Hatchways							
Deck Beam Clamps							
,, ,, Shelf							
Stringers in Hold							
Deck, Lower							
Deck, Upper, how fastened to Beams							

Transoms, material —— or, if none, in what manner compensated for.

Knight-heads, material —— are they free from defects?

Hawse Timbers, material —— are they free from defects?

Bulkheads, No. —— Thickness of ——

Bulkheads, how secured to the sides of the ship ——

Bulkheads, size of vertical angle-iron and their distance apart ——

The Frames or Ribs extend in one length from —— to —— riveted through plates with — in. rivets, about —— apart.

The reverse angle-irons on the floors extend in one length across the middle line from —— to ——

The reverse angle-irons on the frames extend in one length from —— to ——

Keelson, how are the various lengths of plates or angle irons connected?

Plates, Garboard, double or single riveted to keel and at upper edge, with rivets — ins. diameter, averaging — in. from centre to centre of rivet.

Plates, edges from Garboards to upper part of bilge, worked carvel with a lining piece — in. thick, or clincher, double, or single riveted; rivets — in. diameter, averaging — ins. from centre to centre of rivets.

Plates, butts from keel to turn of bilge, worked carvel with a lining piece —— thick double or single riveted; rivets — in. diameter, averaging — ins. from centre to centre of rivets. Do the lining pieces lap over and rivet through the lands of the strake below?

Plates, edges from bilge to planksheer, worked carvel with a lining piece —— thick, double or single riveted; rivets — in. diameter, averaging — ins. from centre to centre of rivets. Do the lining pieces lap over and rivet through the lands of the strake below?

Plates, butts from bilge to planksheers, worked carvel with a lining piece —— thick, or clencher, double or single riveted; rivets — in. diameter,

averaging — ins. from centre to centre of rivets. Breadth of laps in double riveting ——. Breadth of laps in single riveting ——.

Planksheer, how secured to the plating of the sides. (*Explain by a sketch if necessary.*)

Waterway, how secured to the planksheer and to the beams. (*Explain by a sketch if necessary.*)

Side trussing —— breadth and thickness of plates —— how secured ——

Deck trussing —— breadth and thickness of plates —— how secured ——

Deck beams how secured to the side ——

Hold or Lower Deck, how secured to the side ——

Paddle, how secured to the side ——

No. of breasthooks —— crutches —— how are pointers compensated?

What description of iron is used for the angle-iron and plate iron in the vessel?

——— *Builder's Signature.*

WORKMANSHIP.—Are the lands or laps of the clench work in all cases in breadth at least five times the diameter of the rivets in double riveted edges and butts, and at least three times the diameter of the rivets where single riveting is admitted?

Do the edges of the carvel work and of the butts fay close together throughout their length without requiring any making good of deficiencies?

Do the fillings between the ribs and plates fill in solid with single pieces, or are they in short lengths of various thicknesses?

Do the holes for riveting plates to frames, lining pieces, or plate to plate, &c., conform well to each

other? ——and are the rivet holes well and sufficiently counter sunk on the outer plate?

Are there any rivets which either break into or have been put through the seams or butts of the plating?

Her masts, yards, &c., are in —— condition, and sufficient in size and weight.

No.	She has Sails.	Cables, &c.	Fath.	In.	Anchors, and their weights.	No.	Weight.
	Fore Sails,	Chain			Bower		
	Fore Top Sails,	Hempen Stream Cable					
	Fore Topmast Stay Sails,	Hawser			Stream		
		Towlines					
	Main Sails,	Warp					
	Main Top Sails, and	All of —— quality.			Kedge		

Her standing and running rigging —— sufficient in size, and —— in quality.

She has —— long boat and ——

The present state of the windlass is —— capstan —— and rudder —— pumps.

General Remarks.

Statement and date of repairs; extent of corrosion (if any) both internally and externally; and condition of rivets.

1st. On the several parts of the frame, when in place, and before the plating was wrought ——*.

2nd. On the plating during the progress of riveting ——.

3rd. When the beams were in and fastened, and before the decks were laid ——.

4th. When the ship was complete, and before the plating was finally coated ——.

5th. After the ship was launched ——.

* Dates of Surveys held while building, as per Section 17.

In what manner are the surfaces preserved from oxidation?

I am of opinion this vessel should be classed ——.

The amount of the Fee . . £ : : is received by me,
Special £ : :
Certificate (if required) . . . £ : :

Committee's Minute ——, 18—.

Character assigned ——.

(*Surveyor's Signature.*)

SPECIFICATIONS.

HAVING endeavoured to illustrate the plain and ordinary modes of Iron Ship-building, I reserve for the conclusion a few Specifications of various Steam and Sailing vessels. One of these is strictly in accordance with the last published regulations of Lloyd's, and by following the rules there laid down, it is not difficult to discover the correct scantling required for different sized vessels which are to be classed at Lloyd's. The remainder are chosen rather to show instances of vessels which, though differing from Lloyd's rules in many essential points, have nevertheless stood well, and may therefore be useful guides to those who have occasion to construct vessels for peculiar purposes, and wish for examples to guide them.

I could wish to have enlarged this section of my work, but, without the permission of either the owners or the builders, I did not feel myself at liberty to insert some examples that would have been valuable for the objects above-named: other cases, which it was in my power to give, did not afford sufficient interest or variety.

Iron Work of a London River Steamer.

Dimensions, &c.—Length on deck, 126 ft.; breadth, 13 ft.; depth of hold, 7 ft.; draught of water to be 2 ft. 6 in., with machinery and coals on board.

Keel and Stems of 6 × ½ in. bar iron.

Plating.—Garboard strake, ¼ in. thick; bottom and bilges,

$\frac{3}{16}$ in.; sides, $\frac{1}{8}$ in.; all to be flush-jointed and countersunk, riveted. A bar of half-round iron to run all round the gunwale strake and along the sponsons.

Frames to be of 2×2 in. angle-iron, spaced 18 in. apart in centre of the vessel, widening out at both ends of the vessel to 24 inches.

Engine Sleepers to be 12 in. deep and $\frac{1}{4}$ in. thick; and of sufficient length to distribute the weight of the engines and boiler over 30 ft. length of vessel.

Bulkheads and Coal Bunkers.—Bulkheads to be made of $\frac{1}{8}$ in. plates bare in thickness, and the coal bunkers to be $\frac{1}{8}$ in. full.

Iron Work of the Paddle Steamer, "Vernon," built for River Work by Messrs. S. Vernon & Son, 1849.

Dimensions.—Length on the water line, 130 ft.; breadth, 16 ft. 6 in.; depth from skin to underside of deck, 8 ft. 6 in.

Keel Plate to be $\frac{3}{8}$ in. thick, to be made hollow and form a waterway under the flooring plates; the keel plate to be single riveted to the garboard strakes, and to be made of best Staffordshire iron.

Stern Posts to be formed of solid bar iron, $\frac{3}{4}$ in. thick at the fore-part; the after-part to correspond with the lines of the vessel, to be 4 in. wide, with a projection to cover the edges of the plates. The posts to be bent, or worked round to suit the form of the rudder, and to run in upon and be securely fastened to the keel plate, and to have holes for the rudder post and locking bolt, brace for lower part of rudder, and shoe for it to work on. The rudder guards to be $5 \times 1\frac{1}{4}$ in. iron.

Plates to be of best Staffordshire iron, clincher built, with flush butts and rivets. Thickness of garboard strake, fore-and-aft, $\frac{5}{16}$ in.; bottom, up to bilge, for 30 ft. amidships, $\frac{5}{16}$ in.; bottom, up to bilge, for 8 ft. fore-and-aft of this, $\frac{1}{4}$ in.; sides, for 30 ft. amidships, $\frac{1}{4}$ in.; remainder of plating, $\frac{3}{16}$ in. The whole to be single riveted.

Frames to be of $2\frac{1}{2}$ in. angle-iron, $\frac{1}{4}$ in. thick, 2 ft. from centre to centre amidships, and widening to $2\frac{1}{2}$ ft. fore-and-aft; each frame to be in two pieces, and the ends to be connected in the centre of the vessel by a reversed angle-iron, 4 ft. long in the midships, and gradually reduced fore-and-aft; to be securely riveted together, with the flooring plate between them. The frames fore-and-aft of the engine room to be $\frac{3}{16}$ in. thick.

Flooring Plates to be 9 in. deep at the centre by $\frac{1}{4}$ in. thick

under the engines, the remainder $\frac{3}{16}$ in. thick; to have $2\frac{1}{2}$ in. angle-iron riveted to the top of the floorings under the engines, and 2 in. angle-iron riveted to the $\frac{3}{16}$ in. flooring plates. The angle-iron to run well up into the bilge, and to be riveted to the frames for about 35 ft. amidships; and in place of the angle-iron along the top in the remainder of vessel, the plate may be turned over to form a flange.

Deck Beams.—The deck beams to be of angle-iron fastened to every frame, with light iron knees, to be $3 \times 3 \times \frac{1}{4}$ in. for the midships, and $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ in. for the shorter beams, fore-and-aft. Stanchions of $1\frac{1}{4}$ in. round iron to be fixed to every other beam, or where necessary.

Gunwale.—The gunwale to be formed of $2\frac{1}{2}$ in. angle-iron $\frac{1}{4}$ in. thick, riveted to the sides of the vessel, and to a stringer plate 9 in. wide by $\frac{1}{4}$ in., running along the top of the deck beam ends, and riveted to every beam.

Paddle Beams to be made of Kennedy and Vernon's 8 in. patent iron, or upon any other plan of equal strength; and to be attached to sides of vessel by knees of plate iron, the ends outside of vessel to be supported by diagonal stays of $2\frac{1}{2}$ in. round iron.

Bulkheads.—The vessel to be fitted with four water-tight iron bulkheads, $\frac{3}{16}$ in. thick, stiffened with $2\frac{1}{2}$ in. angle-iron, not more than 3 ft. apart. The frames for attaching the midship bulkheads to shell to be $4 \times 4 \times \frac{1}{4}$ in. angle-iron, secured to the shell of vessel with zig-zag riveting.

Rudders.—The vessel to be fitted with a rudder at each end; the rudders to be fitted with locking bolts and levers; the rudder stocks to be not less than 3 in. diameter, with a collar to work on the top of the bar forming the rudder casing, with a brace and shoe at the bottom.

"Iona," Paddle Steamer, built by Messrs. J. and G. Thompson, Glasgow, in 1855, for Messrs. D. Hutcheson and Co., of Glasgow, for Plying betwixt Glasgow and Ardrishaig (Loch Fine).*

Dimensions.—Length of keel and fore rake, 225 ft.; breadth of beam, 21 ft.; depth, 9 ft.; engine room tonnage, $151\frac{1}{10}$; gross tonnage, $324\frac{84}{100}$; speed attained on trial, 20 miles per hour; ordinary speed, about 18 miles per hour; engines (oscillating), 45 in. cylinder and 4 ft. stroke.

* Said to have attained the speed of 20 miles an hour.

Keel, of scrap-iron, 4×1 in.
Frames, angle-iron, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ in.
Main deck beams, $3 \times 2\frac{1}{2} \times \frac{5}{16}$ in.
Cabin sole beams, $2\frac{1}{2} \times 2 \times \frac{5}{16}$ in.
Flooring plates, $10 \times \frac{5}{16}$ and $\frac{1}{4}$ in.
Main deck Stringers, $12 \times \frac{3}{8}$ in.
Bulkheads, $\frac{1}{4}$ in. plates for 3 ft. up ; remainder, $\frac{3}{16}$ in.
Plating, garboard strake $\frac{3}{8}$ in. midships ; $\frac{5}{16}$ in. fore-and-aft ; remaining strakes, $\frac{5}{16}$ in. midships ; and $\frac{1}{4}$ in. fore-and-aft.
Paddle beams, $9 \times 12 \times \frac{3}{8}$ in.

Iron Steam Vessel for the Whitehaven Steam Company, "The Queen," built under Mr. Grantham's superintendence.

Dimensions.—Length between perpendiculars, 160 ft. ; length of keel, 150 ft. ; ditto over all, 179 ft. ; overhang of stern, 8ft. ; beam, 246 ft. ; ditto over all, 40 ft. 6 in. ; depth of hold, $13\frac{1}{2}$ ft. ; quarter-deck, 2 ft. 6 in. high, and about 52 ft. long ; from centre of rudder-post ; sponsons, 3 feet wide at the paddle-boxes.

Keel to be made of the pattern rolled by the Oak Farm Company, $\frac{7}{8}$ in. thick at the bottom, to be previously well jointed, and then to be united by internal plates $\frac{5}{8}$ in. thick, and not less than a foot long, very firmly riveted.

Stem Post to be made of a solid bar, average thickness $2\frac{1}{2}$ in. by 6 in. wide, running 3 feet along the keel, the first length of which must be well riveted to it. This bar to be reduced to $6 \times 1\frac{1}{2}$ in. at the upper part, and the whole to be rebated to receive the plates.

Stern Post to be made of a bar, 6 in. wide, and $3\frac{1}{2}$ in. thick at the main transom, and $6 \times 2\frac{1}{2}$ in. at the keel, and to be secured to the keel like the stem post. Rivets in stem and stern posts to be all 1 in., and drifted quite fair before the rivets are inserted. Projections to be made on them to receive rudder pins.

Plates.—Bottom, for 80 ft. amidships, to be $\frac{9}{16}$ in. ; from this to 20 ft. fore-and-aft, together with the bilges, $\frac{1}{2}$ in. ; remainder of bottom, and from bilge to water line, $\frac{7}{16}$ in. ; remainder of hull, except abaft the paddle-box, $\frac{3}{8}$ in. ; abaft paddle-box, $\frac{5}{16}$ in. ; inside the paddle-boxes, $\frac{3}{8}$ in. ; lower part of bulwark and poop, $\frac{5}{16}$ in. ; bulkhead in lower hold, $\frac{1}{4}$ in. ; bulkhead in upper hold, $\frac{3}{16}$ in. All the horizontal joints to be clincher built, vertical joints flush, and before being riveted to be perfectly fitted.

Rivets for the keel to be 1 in., $\frac{7}{8}$ in. for the bottom generally, and $\frac{3}{4}$ in. for the sideplates, to be of the very best iron, ham-

mered hot, and set up on the inside. The holes to be kept very fairly opposite each other, and to be, for the single riveting 6, and for the double riveting 9, to every lineal foot.

Floorings, for 70 feet midships in engine compartment, to be double angle-iron $3 \times 3 \times \frac{1}{2}$ in. riveted to the shell; between these, strips of 15 in. deep in midships and $\frac{1}{2}$ in. thick are to be inserted, and on the top of these strips are to be riveted pieces of angle-iron $4 \times 4 \times \frac{1}{2}$ in. The remainder of the floor to be attached to the shell by single angle-iron, with strips, to be reduced to $15 \times \frac{3}{8}$ in., and the top angle, $3 \times \frac{3}{8}$.

Keelsons to be of iron, four in number in the engine-room, and two to run fore-and-aft, these to be formed of four bars of angle-iron, $3 \times 3 \times \frac{3}{8}$ in., and a strip, $9 \times \frac{1}{2}$ inch.

Side Frames.—Room and space, 18 in.; Vernon's patent, 4×3 in. overlapping the angle-iron of the flooring 3 ft. at the bilge.

Iron Stringer in the engine-room, $12 \times \frac{3}{4}$ in., about 4 feet above the bilge, riveted to the side frames.

Gunwale to be formed of angle-iron, $4 \times 4 \times \frac{1}{2}$ in., on the upper flanch of which a plate, $18 \times \frac{3}{8}$ in., is to be riveted, extending under the deck plank.

Main Deck Beams to be 3 ft., and 3 ft. 6 in. asunder; to be formed by Vernon's patent angle-iron, 5×3 in.; to run down the sides 18 in., and corner pieces inserted to form a knee.

Hold Stanchions to be round bars; one to each alternate deck beam in the lower hold to be $2\frac{1}{2}$ in., and in the upper, $2\frac{1}{4}$ in. diameter.

Lower Deck Beams to be the same as main deck.

Paddle Beams to be box-beams, 16×12 in.. formed of $\frac{3}{8}$ in. plates, and angle-iron; each beam to be in three parts, and not to cut the sides of the vessel; the part of the beam attached to the vessel's sides to be $2\frac{1}{2}$ ft. deep, and the outer ends 12 in. They are also to be trussed by two rods, extending from the ends of the paddle beams across the deck, and 6 ft. 6 in. above, and supported by iron stanchions, $2\frac{1}{2}$ in. diameter at the top, and $3\frac{1}{2}$ in. at the bottom.

Stays for Paddle Beams.—These to be of round iron, 3 in. diameter, to be riveted at the side of the vessel, at the water-line, with a broad foot, and to reach to the outer end of the paddle-beams, and to be there strongly secured.

Deck Houses to be formed forward of the paddle-boxes, in the usual manner.

Bulkheads.—One at each end of the engine compartments, one in the forehold, one in the stem, and one in the stern. The

thickness of the plates are above described, and they must be supported by half round bars, $3 \times \frac{3}{4}$ in., placed vertically, and 2 feet apart; the angle-iron that secures the bulkhead to the sides to be $6 \times 3 \times \frac{3}{8}$ in., to have a double row of rivets in the outer shell, and not more than 6 to the lineal foot—all to be made water-tight.

Paddle Boxes.—The side next the engine to be made of iron, as before described, and to be worked at both ends into the sponson and deck house, that they may as much as possible support each other, the outer edge to have angle-iron, $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$ in., to which the planking is to be secured. Bars of angle-iron, $3 \times 3 \times \frac{1}{4}$ in., and 3 feet apart, to be riveted vertically on the iron face of the paddle-box, and one piece of angle-iron, $4 \times 4 \times \frac{3}{8}$ in., to be riveted along it horizontally to support the fore-and-aft gangway plank.

Breast Hooks, or crutches, to be made near the stem of the ship, to consist of $\frac{3}{8}$ in. plates, riveted to the side frames.

Hawser Pipes must be of wrought iron, and securely riveted to the ship's side.

Rudder to be entirely of iron, the stock to be 4 in. diameter, and solid, extending the whole length, but tapered off so as when plated not to exceed the width of the stern post; at the back is to be formed an arm, to which the plates are to be riveted; the stock is also to be recessed, same as the stern post, to receive the rudder pins.

Channel Plates, formed of bars, $3 \times \frac{5}{8}$ in., to be secured to the bulwarks running through the main rail, and finishing by an eye to receive the rigging.

"Telegraph," Paddle Steamer, built by Messrs. J. and G. Thompson, Glasgow, in 1853, *for Belfast Steam Ship Company, for Passenger and Cargo Traffic betwixt Liverpool and Belfast.*

Dimensions.—Length, 247 ft.; breadth, 27 ft.; depth, $15\frac{3}{10}$ ft.; engine room tonnage, $341\frac{5}{100}$, gross, $819\frac{55}{100}$; engines, side lever, 440 H.P., with improved feathering paddles; speed attained, $17\frac{1}{2}$ miles per hour; run from Belfast Quay to Liverpool Pier Head, 9 hrs. 25 m.

Keel, of scrap iron, $7 \times 2\frac{1}{2}$; stem, $8 \times 2\frac{1}{2}$ and $6 \times 2\frac{1}{2}$; stern post, $7 \times 2\frac{1}{2}$ and $6 \times 2\frac{1}{2}$.

Frames, of angle-iron, $4 \times 3 \times \frac{1}{2}$ in.; spaced 18 inches from centre to centre.

Floorings, 16 × $\frac{1}{2}$ in. with double angle-iron, 3 × 3 × $\frac{7}{16}$ in.

Keelsons.—Centre keelson of $\frac{3}{8}$ in. plates, and 3 × 3 × $\frac{7}{16}$ in. angle-iron (made a box 12 in. square); sister keelsons, 5 × 3 × $\frac{1}{2}$ in. angle-iron, two bars back to back, and run as far fore-and-aft as possible; two rows of $\frac{3}{8}$ in. wash plates under same.

Plates.—Garboard strake, $\frac{3}{4}$ in.; from ditto to 2 ft. water-line $\frac{5}{8}$ in.; from 2 ft. water line to 5 ft. water line, $\frac{9}{16}$; from 5 ft. water line to 10 ft. water line, $\frac{1}{2}$ in.; from 10 ft. water line to shear strake, $\frac{7}{16}$ in.; sheer strake, $\frac{9}{16}$ in.; all plates, except garboard strake, to be $\frac{1}{16}$ in. thinner fore-and-aft, from 100 ft. midships. Keel, stem, and stern-posts, as also flat of floor in engine space, all double riveted.

Stringers.—Main deck, of angle-iron, 3$\frac{1}{2}$ × 3 × $\frac{7}{16}$ in., with stringer plates, 20 × $\frac{1}{2}$ in. midships; tapering to 16 × $\frac{7}{16}$ in., fore-and-aft; 'twixt deck stringers, of angle-iron, 6 × 3 × $\frac{1}{2}$ in.

Deck beams.—Main deck beams, 8 × 3 × $\frac{1}{2}$ in. angle-iron for 120 ft. midships, and 6 × 3 × $\frac{1}{2}$ in., fore-and-aft; one placed on every alternate frame. Lower deck, cabin, and steerage beams, 6 × 3 × $\frac{1}{2}$ in.; two beam ties riveted to deck beams.

Bulkheads, five in number: one at each end of engine space, one in centre of fore hold, one in fore and one in after peak, made of $\frac{3}{8}$ in. plates, strengthened with 3 × 3 × $\frac{3}{8}$ in. angle-iron, placed 2 ft. apart.

Paddle Beams.—Box beams of iron, 18 × 16 in., formed of $\frac{3}{8}$ in. plates and 3 × 3 × $\frac{3}{8}$ in. angle-iron.

Iron Paddle-wheel Steam Vessel, "Pacific," built, under my superintendence, by Messrs. J. S. Russell and Co., Millwall, London, 1853.

Dimensions.—Length between perpendiculars, 250 ft.; length of keel, about 240 ft.; breadth at paddle-wheels, not less than 32 ft.; breadth over sponsons, 38 ft.; depth at after part of engines, 18 ft.; spar deck, 7 ft. 6 in.; shear of deck forward, about 3 ft.; ditto, aft, about 1 ft. 6 in.

Model.—To be adapted for the highest speed, but, as much as possible, embracing the requisites for carrying a large number of passengers, and a good supply of coals.

Poop to be 7 ft. 6 in. in the clear; to be carried as far forward as the bulkhead of the engine department, or according to plan.

Deck Houses.—Officers' rooms and closets to be made at each

end of paddle-boxes ; also a galley and a long second class saloon on deck, reaching from the fore-part of engine compartment to the forecastle, and the forecastle from forward bulkhead to stem, or according to plan.

Stem Post to be formed of a bar, with the average thickness of 4 × 8 in., wide at the bottom, and tapering to 3 × 6 in. at the top. To be kneed at the lower end, and running into the keel 3 ft.

Stern Post to be formed of a bar 7 × 5 ft. at the transom, and tapered down to 9 × 4 ft. at the keel, and to be kneed similarly to the stem post. Instead of rudder braces, projections to be left on the stern post to receive the rudder pins, which are to be 4 in. diameter, and a heel 5 in. deep, to bear the whole weight of the rudder.

Plates to be best Staffordshire or Shropshire iron, and to be clincher-fastened throughout. The vertical joints to be flush with strips at the back. Garboard strakes, for 150 ft. in midships, $\frac{7}{8}$ in. ; the remainder to be $\frac{3}{4}$ and $\frac{5}{8}$ in. ; bottom, for 140 ft. in midships, $\frac{3}{4}$ in. ; bilges and remainder of bottom, forward and aft, $\frac{5}{8}$ in. ; sides to be $\frac{9}{16}$ in. in midships, and $\frac{1}{2}$ in. at the ends ; sheer strake, $\frac{3}{4}$ in. for 150 ft., and $\frac{5}{8}$ in. the remainder ; inside of paddle-boxes and deck houses, $\frac{3}{8}$ and $\frac{1}{4}$ in. ; water-tight bulkheads in lower hold, $\frac{3}{8}$ in. ; water-tight bulkheads in upper hold, $\frac{1}{4}$ in. ; horizontal plate running round the main deck under the plank to be 2 ft. by $\frac{1}{2}$ in. for 130 ft. amidships, and diminishing to 18 in. forward and aft ; ditto, for the spar deck, 15 × $\frac{3}{8}$ in. ; stern plates to be $\frac{1}{2}$ in.

N.B. Great care must be taken to break the joints of the plates gradually, so as not to cause a weakness in any one part, or to have shoulders at the flush joints.

Frames to be 18 in. apart, from centre to centre, throughout the vessel.

Floorings, for 120 ft. in midships, to be well fitted and riveted to the frame, to be 2 ft. × $\frac{1}{2}$ in., and on the top of these floors are to be riveted angle-iron, 4 × 4 × $\frac{1}{2}$ in. The remainder of the floorings to be reduced to $\frac{3}{8}$ in., and the top angle-iron to 4 × $\frac{3}{8}$ in.

Keelsons.—One main keelson to run fore-and-aft, to be formed of a plate 2 ft. 6 in. × $\frac{3}{4}$ in., to extend from the bottom plates, bisecting the floorings, to which it is secured by angle-iron ; this keelson to have two angle-bars, 4 × 4 × $\frac{5}{8}$ in. to secure it to the shell of the vessel, also two bars on its upper edge, these are riveted to it, and to the floors, with the addition of two horizontal

plates, $18 \times \frac{1}{2}$ in., one on each side of the keelson, also secured to the floors; the remaining four keelsons to run as far fore-and-aft as the form of the vessel will admit; each keelson is to be 15 in. deep; plates and angle-iron to be $\frac{1}{2}$ in.; two wash plates of $\frac{3}{8}$ in. (iron) to extend for 200 ft. between the floors.

Side Frames, for 160 ft. in midships, to be of angle-iron, $6 \times 3 \times \frac{1}{2}$ in., the frames forward to be $5 \times 3 \times \frac{1}{2}$ & $\frac{7}{16}$ in., and those aft $5 \times 3 \times \frac{7}{16}$ & $\frac{3}{8}$ in.; to every alternate frame is to be riveted reversed angle-iron, $3 \times 3 \times \frac{1}{4}$ in., having holes every 6 in. in the outward flanche.

Iron Stringers, to run entirely round the vessel on the level of the lower deck, to be secured to the side frames by the reversed angle-iron, to be composed of a plate $18 \times \frac{1}{2}$ in., and riveted to the upper side of the beams; but in the open space of the engine compartment, where there is no middle deck, there is to be an equivalent fastening, running 10 ft. into each hold.

Gunwale, to be formed by angle-iron, $6 \times 4 \times \frac{1}{2}$ in., placed on the upper side of horizontal deck plate, and riveted to the plates of the bulwarks.

Deck Beams, in main deck, to be every 3 ft. from centre to centre, and to be formed by two bars of angle-iron, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ in., having a strip $8 \times \frac{1}{2}$ in. between them, or by some other plan equally strong, the frames for the hatchways to be formed in the same manner, but with only one piece of angle-iron. Lower deck beams forward to be formed by one bar of iron, $8 \times 3 \times \frac{3}{8}$ in., and beams in the spar deck to be of angle-iron, $8 \times 3 \times \frac{3}{8}$ in. The main deck beams will be secured at the gunwale by angle-plates $\frac{3}{8}$ in. thick by 15 in. on the short sides. Two large beams to be prepared to receive the frames of the engines, as may be required by the engineer.

Paddle Beams to be made of a box form, 21 in. deep at the sides and 18 in. at the centre plates, to be $\frac{1}{2}$ in. thick, stiffened with four bars of angle-iron, $4 \times 4 \times \frac{1}{2}$ in., each beam to be made in three lengths, and united at the sides of the vessel.

Paddle Beam Stays to be double, and to consist of two bars of round iron, $3\frac{1}{2}$ in. diameter, and secured by a broad foot to the vessel's sides, to be trussed above by rods, 2 in. diameter, passing over upright stanchions, 7 ft. 6 in. high $\times 3\frac{1}{2}$ in. and $2\frac{1}{2}$ in. diameter, resting on the gunwale of main deck.

Bulkheads.—Up to main deck, one to be at each end of the engine house, one in forehold, one in the stem, and one in the stern, as hereafter to be determined on. Frames for attaching bulkheads to side of ship to be $6 \times 3 \times \frac{1}{2}$ in., the long leg being

riveted to the shell by two rows of rivets, not closer than $3\frac{1}{2}$ in. All these bulkheads to be stiffened by angle-iron, $5 \times 3 \times \frac{3}{8}$ in., every 2 ft. apart.

Paddle Boxes.—The side next the deck to be of iron, as before described, and worked at both ends into the sponsons and deck-houses, that they may as much as possible support each other; the upper edge to have angle-iron $4 \times 4 \times \frac{1}{2}$ in., to which the timber planking is to be secured.

Hawse Pipes to be of wrought iron, and to be riveted to the shell; to have large cast-iron flanches on the outside.

Rudder to be entirely of iron; the stock to be 6 in. diameter and solid, extending the whole length, but tapering off, so as when plated not to exceed the width of the stern post. At the back is to be formed a tapering arm, to which the plates are to be riveted; projections will be made on the stock, into which the rudder pins will be secured. The plates are to be $\frac{5}{16}$ in. thick; tiller to be of iron, and a spare tiller.

Frame Work, for engines, and boilers, and all provisions for carrying the shafts, including sleepers, stays, and deck beams; these to be provided as may be required for the proper support of the machinery: also all coal bunkers.

Iron Steam Ship, "Tyne," for the Royal Mail Steam Packet Company, of 1850 *tons, old measurement.*

Dimensions.—To be of the following dimensions, viz., 290 ft. length of keel and fore rake; breadth of beam, 36 ft.; depth, from bottom of keel, 30 ft.

Keel, to be of the best scrap-iron, 10 in. deep by 3 in. thick, in as long lengths as practicable, joined together by scarphs of 3 ft. 6 in. long, the rivets for jointing the same to be $1\frac{1}{8}$ in. diameter, the holes to be drilled, and faces of scarphs well fitted.

Stem to be of best scrap-iron, 10 in. broad by 3 in. thick at the bottom, tapering to 7 in. broad by 3 in. thick at the top, the bottom being kneed back so as to meet the keel, and scarphed and riveted in the same manner.

Stern Post to be of best scrap-iron, 10 in. broad by 4 in. thick, kneed forward so as to form part of the keel, and scarphed and riveted as above; strong braces to be forged solid on to the post for hanging the rudder.

Frames to be of angle-iron, $5 \times 3 \times \frac{3}{8}$ in., 15 in. apart, amidships, to 3 ft. before and 3 ft. abaft engine and boiler space, and 18 in. apart fore-and-aft of these, with reverse angle-irons,

$3 \times 3 \times \frac{3}{8}$ in. for 100 ft. amidships; the frames to be of angle-iron $5 \times 3 \times \frac{5}{8}$ in. The whole of them to be in one piece, and butted down about 1 in. on both sides of the keel.

Floors.—The floor plates to be in one piece, 2 ft. deep at centre, by $\frac{1}{2}$ in. thick, the under edge being riveted to the frames, and the upper edge to reverse frames. In engine and boiler space to have an additional angle-iron, $3 \times 3 \times \frac{3}{8}$ in., riveted to the opposite upper edge of floor plates, and extending to the 6 ft. water line.

Bulkheads.—The number of these as may be directed by the Royal Mail Steam Packet Company, the plates to be $\frac{3}{8}$ in. thick at bottom, graduated to $\frac{1}{4}$ in. at the top, riveted to the frames, and strengthened by vertical angle-irons on one side, $3 \times 3 \times \frac{3}{8}$ in., about 2 ft. 6 in. apart, running from floor to main deck; and on the other side by angle-irons, horizontally placed, of same size and distance apart.

Plates: Scantling.—Garboard strake, $\frac{7}{8}$ in. thick; second and third ditto, $\frac{3}{4}$ in.; thence to round of bilge, $\frac{11}{16}$ in.; round of bilge (two strakes), $\frac{3}{4}$ in.; two next strakes, $\frac{5}{8}$ in.; six above these, $\frac{1}{2}$ in.; three above these, $\frac{5}{8}$ in.; one strake above this, $\frac{1}{2}$ in.; top strake, $\frac{5}{8}$ in. The garboard strake to be wrought to shape, and riveted to the keel with a double row of rivets $1\frac{1}{8}$ in. diameter, the longitudinal joints of the outside plating to be overlapped, and vertical joints to be flush, to be riveted to the load water line, with double rows of rivets, and single riveted from thence upwards, the butts of the vertical joints where double riveted to be 8 in. broad, and where single riveted to be $4\frac{1}{2}$ in. broad. The whole of these strips or butts to be $\frac{1}{16}$ in. thicker than the plates to which they are to be attached, and all the rivet holes to be well countersunk.

Beams, Spar Deck, to be of patent beam-iron, 7 in. deep, or bar and angle-irons (having a bead on under edge) of equivalent strength, and to be secured to the ship's side by being riveted to the horizontal shelf or stringer with a requisite roll.

Main Deck to be of patent beam iron, 9 in. deep, or of equivalent strength, by being constructed of bar and angle-irons, as above, with a bead on under edge, and to be secured to the ship's side in same manner as above described, these beams to be of ample strength for the carrying of armament and fitting of capstan fitments, &c.

Lower Deck: to be of similar iron, and 8 in. deep, secured in same manner as above.

Diagonal Plates to be placed on main and spar deck beams, where practicable, before and abaft crank, and all hatches.

Stringers.—Lower deck stringers to be of plate iron, 18 in. broad by $\frac{3}{8}$ in. thick, before and abaft engine room and boiler space, riveted to every beam, and secured to the frames by angle-iron, $4 \times 3 \times \frac{3}{8}$ in.; main deck stringer of plate iron, $20 \times \frac{1}{2}$ in., secured to the frames by angle-iron, $4 \times 3 \times \frac{3}{8}$ in., and riveted to every beam; spar deck stringer of plate-iron, 20 in. broad by $\frac{3}{8}$ in., extending under the gunwale, and riveted to every beam. The main and spar deck stringers to extend round the whole ship, and all secured to plates uniting them together at each end of the vessel. Box stringers to be formed in the engine room, and continued 12 ft. before and abaft the engine room bulkheads, in a line with the under side of the lower deck beams, and to be of the following dimensions, viz.: box, 15×12 in. plates $\frac{3}{8}$ in. thick, and angle-iron $3 \times 3 \times \frac{3}{8}$ in. These stringers to taper away, and become flush at the ends with the reverse frames.

Stanchions.—Malleable iron stanchions for support of decks to be placed fore-and-aft at every third beam, those in the hold to be 3 in. diameter, and if carried to saloon deck to be the same; those between lower and main decks to be $2\frac{3}{4}$ in. diameter, and those between main and spar decks to be $2\frac{1}{4}$ in. diameter, and to be constructed and fitted so as they will suspend as well as support.

Breast Hooks and crutches of sufficient number and strength.

Transoms.—The deck transoms, and one between the main and lower decks, to be made of plates 12 in. wide by $\frac{1}{2}$ in. thick, secured with angle-iron $5 \times 3 \times \frac{1}{2}$ in., and riveted to the frames.

Rudder.—Main spindle of rudder to be of best scrap-iron $7\frac{1}{2}$ in. diameter, fitted with five pintles, of such dimensions as shall be determined upon; also to be fitted with tiller chains, wheel, and all other necessary appurtenances according to detail hereafter described under the head of steering apparatus.

Rivets to be $\frac{3}{4}$ in. diameter, about six in number in each foot of single riveting, and 10 to 12 in each foot of double riveting. On the outside the whole to be flush riveted by countersunk holes. The plates to be riveted to the frames by three or four rivets according to the width of the plate. Behind each frame there will be fitted a filling piece or liner of the necessary thickness. The caulking to be done by chintzing up and so closing the joints, iron to iron, as to make the vessel perfectly water-tight.

Hatchways.—Framing of hatchways and ladder-ways to be of angle-iron, with wood head ledges, and coamings, and all necessary hatches, gratings, and coamings round funnel to be of iron.

Head and Stern to have a handsomely carved head and stern. Figure-head, and such carved work at head and stern as may be required, with all necessary cleats, head rails, timbers, dead-lights, &c. &c.

Hawse Pipes to be of cast-iron, of such size and strength as will be requisite for a ship of this tonnage, four in number.

Hawse Timbers.—Sufficient hawse timbers to take the hawse pipes and knight heads.

Engine Room Beams.—As many iron box beams to be fixed across the engine-room, and of such sizes, as may be required.

Coal Holds or Boxes.—According to engineer's plans.

Foundations under Engines and main keelson to be made of sufficient strength, and according to engineer's plans.

Paddle Beams.—According to engineer's plans.

Additional Shelf or Stringer under Spar Deck.—For the purpose of strengthening the top-sides of the vessel there will run a plate under the shelf of spar deck all round, 2 ft. wide by $\frac{3}{8}$ in. thick, and securely riveted to the reverse frames so as to make the ship double in this part. The quality of the iron to be used in the construction of this vessel to be of the best description.

A First Class Iron Screw Steamer, to be propelled by two direct-acting Engines of 90 *horse power collectively. The "Victor Emmanuel," built by Mr. A. Denny, of Dumbarton,* 1855.

Dimensions.—Length of keel and fore rake, 152 ft.; breadth of beam, 23 ft.; depth moulded, 14 ft.; length of quarter deck, 47 ft.; ditto of forecastle, 27 ft.; tonnage, old measurement, 388; new measurement, 331 gross.

Keel to be of hammered scrap-iron, $8 \times 1\frac{1}{4}$ in., and in long lengths, scarphs, 15 in. long.

Stem and Stern Posts.—Stem of scrap-iron, $8 \times 1\frac{1}{4}$ in. at fore-foot, and $6 \times 1\frac{1}{4}$ in. at head. Stern post screw frame of hammered scrap iron, $5 \times 2\frac{1}{2}$ in.

Frames to be of angle-iron, $4 \times 3 \times \frac{7}{8}$ in., 80 ft. amidships; forward and aft that of $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in., placed throughout the vessel 18 in. apart from centre to centre, and extending from keel to main rail, and from keel to poop and forecastle decks in ordinary lengths. Reverse angle-iron of $3 \times 3 \times \frac{3}{8}$ in., and amidships of $3 \times 3 \times \frac{5}{16}$ in. fore-and-aft, one to each frame, every second one to deck beam knee plate, the rest to between decks.

Floors, formed of a plate $15 \times \frac{3}{8}$ and $\frac{5}{16}$ in., securely fastened to each frame, having on top edge an angle-iron $3 \times 3 \times \frac{3}{8}$ in.

Keelsons, formed by a plate $16\frac{1}{2} \times \frac{5}{16}$ in., let down betwixt floors, and fastened to them by short junks of angle-iron, and having on top edge two rows of $5 \times 3 \times \frac{3}{8}$ in. angle-iron, placed back to back, and securely riveted to reverse bars.

Main Deck Beams, of $6 \times 3 \times \frac{3}{8}$ in. angle-iron, with two bars of angle-iron $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ in. back to back, riveted on upper edge, and spaced throughout the vessel 3 ft. apart, or one to every second frame, and fastened to frames by knee plates, $15 \times \frac{3}{8}$ in.

Poop and Forecastle Beams, of $4 \times 3 \times \frac{3}{8}$ in. angle-iron, one to every second frame, and secured to it by knee plates, $9 \times \frac{3}{8}$ in.

Main Deck Stringers, formed of a plate $30 \times \frac{3}{8}$ in., laid on and riveted to deck beams, and fastened to upper strake of hull by an angle-iron $3 \times 3 \times \frac{7}{16}$ in. This stringer extends from side to side of the vessel at poop and forecastle.

'Twixt Deck Stringers in fore and main holds, two rows of $6 \times 3 \times \frac{3}{8}$ in. angle-iron, 6 in. apart from each other, with the 3 in. flanges riveted to reverse bars, and in engine room two rows of $6 \times 3 \times \frac{3}{8}$ in. angle-iron, spaced 6 in. from each other.

Forecastle and Cabin Sole Stringers, formed of plate $29 \times \frac{3}{8}$ in.

Forecastle and Poop Deck Stringers, formed of plate $23 \times \frac{5}{16}$ in.

Bulkheads.—Four in number, viz., fore peak, and one between fore and main holds of $\frac{3}{16}$ in. plate; engine-room bulkheads of $\frac{5}{16}$ in. plate, and stiffened by vertical bars of $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in. angle-iron. There are likewise bulkheads at after end of forecastle, and front of poop of $\frac{1}{4}$ in. plate.

Coal Bunkers, of $\frac{3}{16}$ in. plate, stiffened with angle-iron, placed one each side of engines and boilers, and between stoke-hole and engine-room across the ship.

Rudder.—Stock of hammered iron, $3\frac{1}{2}$ in. diameter; in case below that, $4\frac{1}{2} \times 2\frac{1}{2}$; back, $2\frac{1}{2} \times \frac{3}{4}$ in., plated with $\frac{1}{4}$ in. plate, and secured to post by three bands.

Outside Plating.—Garboard strake, $\frac{9}{16}$ in.; midships, $\frac{1}{2}$ in. at ends; bottom and round bilge, $\frac{1}{2}$ in.; amidships, $\frac{7}{16}$ in.; at sides, $\frac{7}{16}$ in.; sheer strake, $\frac{1}{2}$ in., amidships, $\frac{7}{16}$; at poop and forecastle, $\frac{3}{8}$ in.; bulwarks, $\frac{1}{4}$ in. All landings to overlap, vertical joints to be flush; butt straps not to be less in thickness than the plates on which they go.

Riveting.—All the keel, stem, and propeller frame, upper edge of garboard strake, and all vertical butts, to be double riveted; the rest to be single. Rivets in keel, stem, and propeller frame to 1 in. diameter; in the rest of the hull, $\frac{3}{4}$ in. diameter.

The Iron Screw Steam Ship, "Loire," of 573 *tons, O. M. and* 70 *H. P., built by Messrs. T. Vernon & Son; designed by Mr. John Grantham,* 1854.

Dimensions.—To be 175 ft. long between perpendiculars, 26 ft. in beam, and 14 ft. in depth from base line to gunwale amidships.

Keel to be made of plate-iron $\frac{5}{8}$ in. thick, dished about 3 inches, and to be 8 inches wide, put together in as long lengths as possible.

Stem Post to be of bar-iron, 6 in. wide and $1\frac{3}{8}$ in. thick; to run into and to be well fastened to the keel.

Stern Post to be of bar-iron, 7 in. wide and 3 in. thick; to be connected with the keel, and an aperture made for receiving the screw, of such size as may be required.

Plates for bottom and bilges, for 120 ft. amidships, $\frac{7}{16}$ in. thick; sheerstrake, $\frac{7}{16}$ in. thick for 120 ft. amidships; remainder of shell, $\frac{3}{8}$ in. thick.

Room and Space to be 18 in. for 60 ft. amidships, and 21 in. fore-and-aft.

Frames to be of angle-iron, $3 \times 3 \times \frac{3}{8}$ in.: an additional angle-iron from bilge to bilge, to be introduced under the engines. A reversed angle-iron of $2 \times 2 \times \frac{1}{4}$ in. to be riveted on each alternate side frame for securing the ceiling to.

Floors to have a plate 15 in. deep $\times \frac{3}{8}$ in. thick, with angle-iron on the top, $3 \times 3 \times \frac{3}{8}$ in.

Crutches of plate-iron at fore-and-aft end, as may be required.

Bulkheads to be four in number and made water-tight; the bottom plates to be $\frac{3}{8}$ in. thick, and remainder $\frac{1}{4}$ in., and stiffened by vertical bars of $3 \times 3 \times \frac{1}{4}$ in. angle-iron, 2 ft. apart. Frames for bulkheads to be 6×3 in. angle-iron, the wide flange to be next the shell, to which it must be attached by a double row of rivets.

Keelsons in the hold to be three in number, to be formed of plates $\frac{3}{8}$ in. thick, let down between the floors and secured to them by 3 in. angle-iron. Centre keelson to have two angle-iron bars to run fore-and-aft; and the side keelsons one angle-iron bar, and to be riveted to the floors and to the keelsons. These angle-iron bars to be $3 \times 3 \times \frac{3}{8}$ in.

Gunwale angle-iron to be $3 \times 3 \times \frac{3}{8}$ in., to be firmly riveted to the side of the vessel.

Stringer to be attached to the gunwale all round the vessel, to be 21 in. wide by $\frac{3}{8}$ in. thick amidships, and diminishing forward

and aft to 15 in. by $\frac{3}{8}$ in. thick. A stringer at line of lower deck to be formed of $6 \times 3 \times \frac{3}{8}$ in. angle-iron, secured to side frames by angle-iron, $3 \times 3 \times \frac{3}{8}$ in.

Deck Beams for main deck to be one to every alternate side frame; to be made of $6 \times 3 \times \frac{3}{8}$ in. angle iron, and $4 \times 3 \times \frac{5}{16}$ in. for the ends, as required; to be well secured to sides of vessel by plate knees, and to be supported by iron stanchions 2 in. diameter, one to every other beam.

Lower deck beams to be, in the furthest fore hold, say for about 30 ft., same as those for main deck; hatchways to be formed in the decks where required.

Engine Beds to be made to drawings, to be furnished by the engineer.

Rudder to be entirely of iron, strongly framed, and covered with plates $\frac{3}{16}$ in. thick. Rudder stock to be $4\frac{1}{2}$ in. diameter, and fitted close to the upper deck.

Tiller to be of iron suitable for the vessel.

Rivets.—Those for the keel, stem, and stern post to be 1 in. diameter; those for plating, $\frac{11}{16}$ in.; and for bulkheads, floors, &c., $\frac{9}{16}$ in.; all single riveted, about $5\frac{1}{2}$ rivets per lineal foot. Rivets in frames about 6 in. apart, and the spaces under the frames to be filled in with iron liners. All the holes on the outside shell to be countersunk.

Joints.—Horizontal joints to be clincher fastened, with plates outside and inside of each other alternately. Vertical joints to be flush, and covered with a strip inside, of the same thickness as the plate.

The Iron Screw Collier, "James Kennedy," of 616 *tons, built by Messrs. T. Vernon & Son, and designed by Mr. John Grantham,* 1857.

General Description.—The vessel to have a large open hold and the full depth, and the engines placed in the stern; main deck to be flush fore-and-aft, and to have one long hatch. A round stern, a straight stem, and no ornamental work.

Dimensions.—Length between perpendiculars, 175 ft.; beam, 27 ft.; depth from top of keel to gunwale, 16 ft. 9 in.

Keel of best best plate, 1 in. thick, to be hollowed about 8 in. wide and $1\frac{1}{2}$ in. deep.

Stem in one bar, $7 \times 2\frac{3}{4}$ in., running 5 ft. into keel.

Stern Post and Rudder Post, and frame for screw propeller opening, to be of the best hammered iron, 7 in. wide, and averaging

$5\frac{1}{2}$ inches thick; the whole to be welded and made in one piece. The after post to be levelled regularly on the forward edge.

Rudder to be of wrought-iron, all in one piece, and with solid gudgeons to be stepped on the heel of stern post. Rudder to be plated with $\frac{1}{4}$ in. plates, the stock to be $4\frac{1}{2}$ in. diameter.

Frames to be 18 in. apart throughout the vessel, and made of $4 \times 3 \times \frac{7}{16}$ in. angle-iron; to have a reversed angle-iron, $3 \times 2\frac{1}{2} \times \frac{3}{8}$ in. on each alternate frame, extending from plating at top of floors to the gunwale.

Double Bottom, for water ballast, to be 3 ft. deep, and the entire length of main hold; to be secured to ship's side at bilges by angle-iron, about $5 \times 5 \times \frac{1}{2}$ in., and at the bulkheads by angle-ron, $3 \times 3 \times \frac{7}{16}$ in. The flooring plates to be attached to every rame, and to be 3 ft. deep and $\frac{5}{16}$ in. thick, secured to false bottom by angle-iron $3 \times 3 \times \frac{3}{8}$ in. The plating of false bottom to be $\frac{3}{8}$ in. thick.

Three manways to be made in each floor, and manways also to be in the upper plates; the latter to have strong cast-iron covers well bolted. Two fore-and-aft wash plates, or keelsons, to run between the floors, and to be secured to them by angle-iron; all to be the same strength as the floors. Side frames of ship to be so made that the false bottom may be riveted to the outside shell; and the side frames to have a foot turned upon them 2 ft. long, which will extend over the false bottom and be riveted to it, as shown in the section; small knee plates to be fixed upon the corner where the foot is turned up. The frames and the reversed angle-iron to be extended to the extreme end of the foot.

The iron deck over the forecastle tank, and the tank in the after compartment, to be made and fastened in the same manner as above. The pipe for filling the main hold to be $3\frac{1}{2}$ in. diameter, with a brass cock and index; to have also a pipe and two-wayed cock for turning the water ballast into the engine room, or through the bottom of the ship. These to be placed in the engine room where the engineer can see them. There are also cocks and pipes, $2\frac{1}{2}$ in. diameter, to be provided for filling fore peak and after compartment; and a cock for running water off the top of false bottom. All these cocks to have handles leading into convenient places, with index to each, and all to be covered up and locked: proper air pipes to be made in connection with these compartments.

Floor plates in the engine and boiler room where there is no false bottom, to be 17 in. deep and $\frac{7}{16}$ in. thick, with an angle-iron on upper edge, $3 \times 3 \times \frac{3}{8}$ in. thick; this angle-iron to be doubled underneath the engines.

Deck Beams to be made of patent bulb-iron, 7 in. deep and $\frac{7}{16}$ in. thick, with two bars of $2\frac{1}{2} \times 2\frac{1}{2}$ in. angle-iron on top edge, and to be secured to side frames by knees of plate-iron 18 in. deep : the largest bulb pattern that is made of that depth of beam to be used. The beams for main deck to be 3 feet apart, or one fastened to each alternate frame.

The hold beams to be formed of a plate 9 in. deep by $\frac{3}{8}$ in. thick ; to have four bars of angle iron $3 \times 2\frac{1}{2} \times \frac{1}{2}$ in. riveted to it, to form a double T ; or common T iron, having the same thickness, and being 6 in. wide on the top, may be substituted for the angle-irons. All fore-and-aft carlings to be made of same section of iron as beams.

An iron stanchion, $2\frac{1}{2}$ in. diameter, to support each hold beam; and $2\frac{1}{4}$ in. diameter above to support main deck beams. Two tie bars of $16 \times \frac{7}{16}$ in. iron to run fore-and-aft on main deck beams, and to be secured thereto; also two longitudinal tie bars riveted to top of hold beams, each to be formed of two bars of angle-iron $3 \times 3 \times \frac{1}{2}$ in.

Gunwale to be formed of angle-iron, $4 \times 4 \times \frac{7}{16}$ in. The stringer plate to be $24 \times \frac{9}{16}$ in. at the midships, for 120 ft. in length, and to be gradually reduced to 18 in. wide at each end of vessel ; to be well secured to the gunwale angle-iron and deck beams. Joints of the stringer plate to lap 12 inches, or have joining pieces 24 in. long riveted on each butt, with three rows of rivets on each side of butt. A plate, 12 in. wide and $\frac{3}{8}$ in. thick, to be placed on edge upon the stringer plate, and to be fastened thereto by $3 \times 3 \times \frac{1}{2}$ in. angle-iron. This plate to run parallel with the sheerstrake of the ship, and about 7 inches distance from it, thereby forming a groove to receive the feet of the wood stanchions, where they will be secured by bolts through and through. An additional angle-iron, $3 \times 3 \times \frac{1}{2}$ in., to be fixed along the inside edge of the stringer plate, to form an abutment for the deck plank.

Openings in the gunwale plate, about $4\frac{1}{2}$ ft. by about 7 in. for letting the water off the deck, to be four in number on each side of ship, and to have plates over them to compensate for the loss of strength.

Hold Stringers to be of angle-iron, $4 \times 4 \times \frac{7}{16}$ in., with a plate $16 \times \frac{7}{16}$ in. running fore-and-aft on hold beams.

Bulkheads to be made of $\frac{3}{8}$ in. plates, perfectly water-tight and stiffened with vertical bars of angle-iron $3 \times 2\frac{1}{2} \times \frac{3}{8}$ in., $2\frac{1}{2}$ ft. apart; each alternate vertical bar to have a reversed angle iron of same section up to the height of lower deck. The after bulkhead of the fore hold to have additional stiffening, by having the sides of coal

bunkers firmly riveted to it by angle-iron ; frames of all bulkheads to be of angle-iron, $6 \times 3 \times \frac{7}{16}$ in., the wide flange next the shell, to which it is to be attached by two rows of rivets ; bulkheads to be three in number.

The bulkheads to be further connected to sides of vessel by knees or brackets of plate-iron.

Forecastle Floor to be made of $\frac{5}{16}$ in. plates, and to be water-tight. Floors for cabin to be made in same manner.

Plates of Hull.—Garboard strake, $\frac{9}{16}$ in. thick ; bottom and bilges throughout, $\frac{1}{2}$ in. ditto; sides, except sheerstrake, $\frac{7}{16}$ in. ditto; sheerstrake amidships, to be carried 12 in. above the line of gunwale, $\frac{9}{16}$ in. ditto ; sheerstrake, forward and aft, $\frac{1}{2}$ in. ditto.

Riveting.—The keel, stem, and stern posts, and the longitudinal joints of the garboard strake to be double riveted ; also the butts of all outside plating to be double riveted, with rivets of the required diameter and distance apart as per Lloyds' rules ; all the welts to be $\frac{1}{16}$ in. thicker than the plates.

Keelsons in the engine room to be made suitable for the engines and boiler, and to be formed of plates and angle-iron ; the plans to be furnished by the engineers.

Crutches, or Aprons, to be made for fore and after ends, to be of plates $\frac{7}{16}$ in. thick, of sufficient number, and securely riveted to the frames.

Iron Screw Steam Ship of 655, *O. M., and* 90 *horse power,* "*Empress Eugènie,*" *designed by Mr. John Grantham,* 1855.*

General Description.—The main deck to be flush fore-and-aft, and raised forecastle at bow. The hull to be divided into five compartments by iron bulkheads, the engine-room being about one-third from stern, leaving two holds forward and one aft. A lower deck in the hold furthest forward, and one in the forecastle.

Dimensions.—To be 185 ft. long between perpendiculars ; 27 ft. beam ; 15 ft. in depth from base line to gunwale amidships.

Keel to be made of plate-iron $\frac{5}{8}$ in. thick, dished about 3 in., and to be 8 in. wide, put together in as long lengths as possible.

Stem Post to be of bar-iron, 6 in. wide, and $1\frac{3}{8}$ in. thick, to run into and to be well fastened to the keel.

Stern Post to be of bar-iron 7 in. wide, and 3 in. thick, connected with the keel, and an aperture made for receiving the screw of such size as may be required.

* This vessel was intended for a light draught of water.

Plates for bottom and bilges, for 100 ft. amidships, to be $\frac{1}{2}$ in., remainder $\frac{7}{16}$ in.; sides, for 100 ft. amidships, $\frac{7}{16}$ in.; sheerstrake, $\frac{1}{2}$ in. thick, for 120 ft. amidships. Remainder of shell $\frac{3}{8}$ in.

Boom and Space to be 18 in. for 100 ft. amidships, and 21 in. forward and aft.

Frames to be of angle-iron $3 \times 3 \times \frac{7}{16}$ and $\frac{3}{8}$ in. An additional angle-iron from bilge to bilge to be introduced under the engines.

A reversed angle-iron, of $2 \times 2\frac{1}{4}$ in. to be riveted on each alternate side frame, for securing the ceiling to.

Floors to have a plate 15 in. deep and $\frac{3}{8}$ in. thick, with angle-iron on the top, $3 \times 3 \times \frac{3}{8}$ in.

Crutches of plate-iron at fore-and-aft end, as may be required.

Bulkheads to be four in number, and made water-tight; the bottom plates $\frac{3}{8}$ in. thick, and remainder $\frac{1}{4}$ in., and stiffened by vertical bars of $3 \times 3 \times \frac{1}{4}$ in. angle-iron, 2 feet apart. Frames for bulkheads to be 6×3 in. angle-iron, the wide flange to be next the shell, to which it must be attached by a double row of rivets.

Keelsons in the hold to be three in number, to be formed of plates $\frac{3}{8}$ in. thick, let down between the floors, and secured to them by 3 in. angle-iron.

Centre keelson to have two angle-iron bars, $6 \times 3 \times \frac{7}{16}$ in., to run fore-and-aft, and the side keelsons one angle-iron bar, $6 \times 3 \times \frac{3}{8}$ in., and to be riveted to the floors and to the keelsons.

Gunwale angle-iron to be $4 \times 3 \times \frac{7}{16}$ in., to be firmly riveted to the side of the vessel.

Stringer to be attached to the gunwale all round the vessel, to be 21 in. wide by $\frac{7}{16}$ in. thick amidships, and diminishing forward and aft to 18 in. by $\frac{3}{8}$ in. thick. A stringer at line of lower deck to be formed of two bars of angle-iron $6 \times 3 \times \frac{3}{8}$ in. secured to side frames by angle-iron, $3 \times 3 \times \frac{3}{8}$ in. Joints of stringers to be double riveted.

Deck Beams for main deck to be one to every alternate side frame; to be made of $6 \times 3 \times \frac{3}{8}$ in. angle-iron, and $4 \times 3 \times \frac{5}{16}$ in. for the ends, if required; to be well secured to side of vessel by plate-knees, and to be supported by iron stanchions 2 in. diameter, one to every other beam. Lower deck-beams to be same as those for main deck.

Hatchways to be formed in the decks where required.

Engine Beds to be made to drawings, to be furnished by the engineer.

Rudder to be entirely of iron, strongly framed, and covered with plates $\frac{3}{16}$ in. thick. Rudder stock to be $4\frac{1}{2}$ in. diameter, and fitted close to the upper deck.

Tiller to be of iron suitable for the vessel.

Rivets.—Those for the keel, stem, and stern posts to be 1 in. diameter, those for plating $\frac{11}{16}$ in., and those for bulkheads, floors, &c. $\frac{9}{16}$ in. All single riveted, about $5\frac{1}{2}$ rivets per lineal foot; rivets in frames about six inches apart, and the spaces under the frames to be filled in with iron liners. All the holes on the outside shell to be countersunk.

Joints.—Horizontal joints to be clincher fastened with plates outside and inside of each other alternately. Vertical joints to be flush, and covered with a strip inside of the same thickness as the plate.

Iron Screw Steamers "Silistria" and "Sardinian," to be propelled by two direct-acting Engines, of 140 *horse power collectively. Built by Mr. Alexander Denny, of Dumbarton,* 1854 *and* 1855.

Dimensions.—Length of keel and fore rake, 217 ft. ; breadth of of beam, 28 ft. ; depth of hold, 15 ft. 8 in. ; length of quarter deck, 65 ft. ; height of ditto, 5 ft. 6 in. ; length of topgallant forecastle, 40 ft. ; height of ditto, 5 ft. 6 in ; tonnage, O. M., 835 ; ditto, N. M., $702\frac{15}{100}$; engine room, $224\frac{69}{100}$.

Keel to be of best hammered scrap-iron, $8 \times 2\frac{1}{2}$ in., in 43 ft. lengths. Scarphs to be 22 in. long, and properly fitted.

Stem and Stern Posts to be of the best hammered scrap-iron, $8 \times 2\frac{1}{2}$ in. at fore foot, and tapering to $6 \times 2\frac{1}{2}$ in. at head, and properly scarphed to keel. Stern post, 6×4 in.

Frames to be of angle-iron, $4\frac{1}{2} \times 3 \times \frac{1}{2}$ in., spaced 15 in. throughout the vessel, extending from keel to main rail, and forward and aft from keel to forecastle and poop deck.

Floors of plate-iron, $20 \times \frac{3}{8}$ in., one to each frame, and securely riveted to it; on top edge a stiffening reverse bar of $3 \times 3 \times \frac{3}{8}$ in. angle-iron.

Reverse Bars to be of angle-iron, $3 \times 3 \times \frac{3}{8}$ in., one to each frame extending to gunwale, and every other one to lower decks.

Keelsons of plate-iron, $20 \times \frac{3}{8}$ in., let down betwixt floors, having on top edge two bars of $5 \times 3 \times \frac{1}{2}$ in. angle-iron, which secure it to reverse bars, and short junks of $3 \times 3 \times \frac{3}{8}$ in. angle-iron at each end, which secure it to floors. Bilge keelsons of $\frac{3}{8}$ in. plates, with two bars of $5 \times 3 \times \frac{1}{2}$ in. angle-iron placed and secured in a similar manner to the main.

Main Deck Beams of bulb-iron, $8 \times \frac{1}{2}$ in., one to each alternate frame, and riveted properly to side frames by two knee plates, $16 \times \frac{5}{16}$ in. with two bars of $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in. angle-iron on top edge.

Lower Deck Beams formed by a plate, $8 \times \frac{1}{2}$ in., having on top and bottom edges two bars of $4 \times 3 \times \frac{1}{2}$ in. angle-iron, and spaced 10 ft. apart; ends securely riveted to lower deck stringers.

Poop and Forecastle Deck Beams of $4\frac{1}{2} \times 3 \times \frac{7}{16}$ in. angle-iron; poop and forecastle sole beams of $8 \times 3 \times \frac{1}{2}$ in. angle-iron; and all sufficiently connected to ship's side by knee plates.

Main Deck Stringers of plate.iron $34 \times \frac{1}{2}$ in. on top of beams, extending from poop to forecastle, and securely fastened to beams and gunwale; angle-iron cross stringers of similar dimensions, all placed before and abaft poop and forecastle bulkheads; poop and forecastle sole stringers $30 \times \frac{7}{16}$ in. plate; poop and forecastle deck stringers $23 \times \frac{5}{16}$ in. plate; lower deck stringers of $8 \times 3 \times \frac{1}{2}$ in.; 6 in. apart.

Bulkheads five in number. Engine room bulkheads of $\frac{3}{8}$ in. plate, the rest $\frac{5}{16}$ in., and all stiffened by $4 \times 3 \times \frac{3}{8}$ in. angle-iron, placed 3 ft. apart. These bulkheads are to be caulked, and made perfectly water-tight.

Coal Bunkers formed of $\frac{3}{16}$ in. plate, stiffened with angle-iron, to be placed on either side of engine, and across the vessel between engine room and stoke hole.

Rudder.—Stock to be hammered scrap-iron, $4\frac{1}{2}$ in. in diameter in rudder case, below that to be 5×3 in., and to be plated with $\frac{5}{16}$ in. plates, and secured to post with four bands.

Outside Plating.—Garboard strake to be $\frac{11}{16}$ in. thick; second strake from keel $\frac{5}{8}$ in. thick; all the bottom and round bilge $\frac{5}{8}$ and $\frac{9}{16}$ in. ditto; sides $\frac{9}{16}$ and $\frac{1}{2}$ in. ditto; sheerstrake $\frac{5}{8}$ and $\frac{9}{16}$ in. ditto; bulwarks, quarter forecastle, $\frac{3}{8}$ in. ditto; poop $\frac{5}{16}$ in. ditto. All the landings to overlap, and vertical joints to be flush. Butt straps not to be less in thickness than the plates on which they go.

Riveting.—All the keel, stem, and propeller frames to be double riveted, and likewise the bottom and round the bilge, to the 10 ft. water-line, to be double riveted. Rivets in keel, stem, and stern post to be $\frac{7}{8}$ in. diameter. The rest to be $\frac{3}{4}$ in. diameter.

Iron Screw Steam Ship, "Aden," built by Messrs. Summers & Day, Southampton, for the Peninsular and Oriental Company, 1856.

Dimensions.—Length between perpendiculars, 227 ft. 6 in.; breadth, 29 ft. $9\frac{1}{2}$ in.; depth, from floor to deck, 19 ft.; tonnage, O. M., 985; 210 horse power.

Keel to be formed of a solid bar, $10 \times 2\frac{1}{2}$ in.

Stem to be formed of a solid bar, $10 \times 2\frac{1}{2}$ in. at bottom; ditto, $5\frac{1}{2} \times 2$ in. at top.

Stern Post to be formed of a solid bar, 10×4 in.

Plates.—Garboard strake, $\frac{11}{16}$ in.; bottom to bilge, $\frac{9}{16}$ and $\frac{1}{2}$ in.; sides, $\frac{7}{16}$ in.; wales, $\frac{1}{2}$ in.; top sides to poop, $\frac{3}{8}$ in.

Frames, 18 in. from centre to centre. All frames in engine room double; every alternate frame beyond engine room, doubled. Frames amidships $4 \times 3\frac{1}{2} \times \frac{7}{16}$ in.; reverse angle-irons, $3\frac{1}{2} \times 3 \times \frac{3}{8}$ in.; floors, depth, 18 in.

Stringers.—One, under main deck, running all the length fore-and-aft., 2 ft. deep, thickness $\frac{1}{2}$ in., with an angle-iron top and bottom of it, $4 \times 4 \times \frac{1}{2}$ in. Stringer running fore-and-aft under cabin deck, 22 in. deep, $\times \frac{1}{2}$ in., with an angle-iron at its top and bottom edge.

Beams, 3 ft., centre to centre, and made of rolled beam-iron, 9 in. deep.

Iron Screw Collier, "William Cory," built by Messrs. C. Mitchell & Co., Low Walker, Newcastle-on-Tyne, 1857.

Dimensions.—Length all over, 252 ft.; length on 11 ft. water line, 240 ft.; beam, moulded, 35 ft.; depth, 18 ft. 9 in.; tonnage, B. M., 1500.

Keel and Stem, of hammered iron, $11 \times 2\frac{1}{2}$ in., in long lengths, with strong scarphs.

Stern Post and Screw, frame of hammered iron, 11×5 in., with boss for screw shaft, as required.

Rudder Stock to be 5 in., with $\frac{5}{16}$ in. plates on blade.

Frames, of angle-iron, $5 \times 3\frac{1}{2} \times \frac{9}{16}$ in., spaced 18 in. from centre to centre throughout. In holds, each frame in three lengths, one to extend across the bottom from bilge to bilge, terminating at iron ceiling, and the others to extend down each side of ship, from gunwale to iron ceiling, where a knee is to be formed, and the frame returned on tops of ceiling as far as is requisite to maintain equal strength; these knees are to be strengthened by a knee plate, not less than 30 in. sided, and $\frac{9}{16}$ in. thick. Fore-and-aft of holds the frames to be in two lengths, as usual; each frame to be well riveted to plating and iron ceiling.

Floorings on every frame throughout, those in holds to be formed of plates $20 \times \frac{1}{2}$ in.; fore-and-aft to be of increased depth to suit the form of ship.

Reverse Angle-Irons throughout to be angle-iron $3\frac{1}{2} \times 3 \times \frac{1}{2}$ in, well riveted to frames and floorings. In holds, to be on every frame, extending down alternately from gunwale and from 18 in. above hold beams to iron ceiling, also on top edge of each floor, from bilge to bilge fore-and-aft, as required.

Keelsons in holds to be seven in number, formed of plates $24 \times \frac{9}{16}$ in. in as long lengths as possible, with two angle-irons, $3 \times 3\frac{1}{2} \times \frac{1}{2}$ in. riveted on each edge, to be strongly riveted to reverse angle-irons. Bulkheads and iron ceiling beams. Keelsons fore-and-aft as required.

Bilge Keels to be placed each side of keel, and formed of bulb beam-iron $8 \times \frac{9}{16}$ in., with two angle-irons $6 \times 4 \times \frac{1}{2}$ in., well riveted to bottom plating ; each bilge keel to extend not less than 100 ft. amidships.

Water Ballast Chambers to be perfectly water-tight, and formed by the bottom plating, and a plate-iron ceiling extending from bilge to bilge in the holds, and placed 4 ft. above the tops of keel; this ceiling to be of plate-iron, not less than $\frac{7}{16}$ in. thick, attached to athwart ship beams resting on keelsons; these beams to be formed of two angle-irons, $4 \times 3 \times \frac{7}{16}$ in., and $3 \times 3 \times \frac{3}{8}$ in., riveted together, and to iron ceiling, keelsons, and frames ; one of these beams to be over each flooring. A knee plate, $\frac{1}{2}$ in. thick, and extending at least 3 ft. along ceiling beams, to be placed on each frame at bilge under ceiling plate, and well riveted to frames and ceiling beams. The water-tight joints, when the iron ceiling meets the outside plating and bulkheads, to be formed as follows :—The edge plate of iron ceiling all round inside holds to be $\frac{1}{2}$ in. thick, and of such a quality that a 6 in. flange can be turned upon its edge without any loss of strength or soundness; this flange to be on the upper side, and double riveted to outside plating and bulkheads, and being carefully worked and caulked, will form the water-tight joint between iron ceiling and hold of ship. Air and other pipes, cock, &c., as required, for rapidly filling and discharging the water ballast, as may be found requisite.

Bulkheads to be five in number, of $\frac{7}{16}$ in. plate, stiffened with vertical bars of angle-iron, $3 \times 3 \times \frac{3}{8}$ in., spaced about 24 inches apart. To be caulked and made water-tight, excepting the fore-peak bulkhead. All bulkheads are to be fitted with large brass cocks, placed as low as possible, with handles leading to the deck, to be used in case of leakage. Each bulkhead to have double angle-irons on top edges, same as deck beams.

Engine and Boiler Seating to be formed of stout plate and angle-iron, as required, for the secure fixing of engines and boilers.

Coal Bunkers to be capable of containing 150 tons of coals; plating to be not less than $\frac{3}{16}$ in. thick, stiffened by angle-iron $3 \times 3 \times \frac{3}{8}$ in., spaced about 30 in. apart ; iron stays across bunkers, as requisite, to be fitted with four feeding and two trimming doors, and scuttles on deck, as required. Along side boilers the upper edge

of bunkers to have angle-iron to form the boiler hatch, with short beams to ship's sides.

Hold Beams of plate-iron, $10 \times \frac{1}{2}$ in., with two angle-irons, $5 \times 3 \times \frac{7}{16}$ in., riveted on top edge, and two ditto on bottom edge, and to have a plate, $12 \times \frac{3}{8}$ in., riveted on top of each beam, to be spaced not more than 9 ft. from centre to centre; to be well secured to frames and hold stringers.

Hold Stringers to extend the length of vessel, to be formed of plates, $27 \times \frac{1}{2}$ in., in long lengths, well riveted to hold beams, and secured to reverse angle-irons and bulkheads by angle-iron, $6 \times 4 \times \frac{1}{2}$ in.

Clamp Plate.—To have a clamp plate $18 \times \frac{1}{2}$, extending all round the vessel, attached to frames immediately above hold stringer, and firmly riveted to reverse angle-irons, and to gunwale stringer angle-iron.

Hold Stanchions, of 3 in. round iron, strongly secured to deck and hold beams, and iron ceiling, to be placed under and over every hold beam: at hatchways to be on each side.

Deck Beams to be one on every alternate frame, formed of patent beam-iron, $8 \times \frac{3}{8}$ in., with two angle-irons, $3 \times 3 \times \frac{3}{8}$ in., riveted to the upper edge. Hatchway beams and framing of additional strength, as required.

Knee Plates of plate-iron, not less than $\frac{1}{2}$ in. thick, and not less than 18 in. sided, to be riveted to each deck and hold beam, and frame at side of ship.

Gunwale Stringer of plate-iron, $27 \times \frac{1}{2}$ in. for 150 ft. amidships, tapering to $20 \times \frac{1}{2}$ in. fore-and-aft, to be in long lengths, and attached to sheerstrake by an angle-iron, $6 \times 4 \times \frac{1}{2}$ in. on upper side, double riveted on each flange.

Deck Ties of plate-iron, $14 \times \frac{3}{8}$ in., in long lengths on each side of hatchways, and extending the entire length of vessel, also placed diagonally, and well riveted to deck beams and gunwale stringer.

Forecastle Sole Beams of angle-iron, $5 \times 3 \times \frac{1}{2}$ in., spaced one on each alternate frame, with fore-and-aft stringer on the under side, of angle-iron, $6 \times 4 \times \frac{1}{2}$ in., riveted to each frame beam.

Top Gallant Forecastle Beams of angle-iron, $5 \times 3 \times \frac{1}{2}$ in., spaced as deck beams.

Sundry Fittings.—Mast and bitt partners, and other strengthening plates and angle-iron as required.

Plating.—Keel strake $\frac{12}{16}$ of an inch; bottom, bilge, and sheer strake, $\frac{11}{16}$ of an inch; bilge plate in line of iron ceiling, $\frac{3}{4}$ of an inch; sides $\frac{9}{16}$ of an inch. The gunwale to be further strengthened by a plate $15 \times \frac{1}{2}$ in., worked on and secured to the outside of sheer-

strake in as long lengths as possible, to break joint with sheer strake. The sheer strake to be carried 10 in. above gunwale stringer all round the ship. All the plating and angle-iron to be worked in as long lengths as possible, with strong joints, to maintain equal strength throughout. All laminated or defective material to be rejected, and both workmanship and material throughout to be sound and of the best quality.

Riveting.—The keel and stern to be double riveted, and the stern post and propeller frame to be treble riveted with $1\frac{1}{8}$ in. rivets. All butt joints in stringer plates and deck ties to be treble riveted; all butt joints in outside plating, plate iron ceiling, floor-plates, and keelsons, to be double riveted. The rivets to be countersunk on outside plating, plate iron ceiling, and gunwale stringer; bottom, bilge, keel, stem, and stern post rivets to be left full, and not made quite flush.

Painting, &c.—All the iron work to receive at least three coats of good oil paint; the bulwarks, deck fittings, and houses to be well painted. All iron work to be well painted with red lead, before receiving the wood work.

Iron Screw Steamers, "Alma" and "Nubia," built for the Peninsular and Oriental Steam Navigation Company, by John Laird, Esq., of Birkenhead.*

Dimensions.—Length between perpendiculars, 292 ft.; breadth of beam, 396 ft.; depth in clear hold, 28 ft.; 2,226 tons, O.M.

Keel of bar iron, 10×5 in.

Stem, 10 in. broad at bottom, by $4\frac{1}{2}$ in. thick; where the cutwater comes in the stem, to be $9 \times 3\frac{1}{2}$ in.

Stern Post, 11 in. by 5 in. thick, tapering to $5 \times 3\frac{1}{2}$ in. at the upper deck, and a heel left in the after side to bear the rudder, with eyes for the pintles, and turned so as to form a knee forward on the keel. The screw port to be forged in one piece, to suit the drawings, or as engineers may require.

Frames of angle iron $6 \times 4\frac{1}{2} \times \frac{1}{2}$ in. for 130 ft. amidships, 18 in. from centre to centre, and fore-and-aft that $5 \times 3\frac{1}{2} \times \frac{7}{16}$ in., the same distance apart. In engine and boiler space the frames to be doubled in the bottom, and a reverse angle-iron in every second frame from gunwale to gunwale, $3\frac{1}{2} \times 3 \times \frac{7}{16}$ in., the whole length of vessel, for fastening the ceilings to.

Plates.—Garboard strake for 130 ft. amidships $\frac{7}{8}$ in., plates,

* This vessel lately made an extraordinary run with the Indian mails to Suez.

as broad as can be procured or worked ; the remainder, fore-and-aft, $\frac{3}{4}$ in. Bottom plates $\frac{5}{8}$ in. to the wales, for 130 ft. in midships. Forward and aft of this $\frac{9}{16}$ in., from the wales to the gunwale $\frac{1}{2}$ in., except two plates 2 ft. 9 in. broad by $\frac{3}{4}$ in. thick to form the wales; all double riveted from keel to gunwale, and all double butts to be flush. The upper strake to go to top of waterway. All spaces formed by the projection of the plates to be fitted with liners, so as to avoid small pieces and rings being used. The butts to be perfectly close as well as the seams, as no piece will be allowed to be put in and caulked over. The counter sinking to be carefully done, and all the rivets to be full and smooth outside of plates, and to be chipped down while hot. The greatest care to be taken in punching, to prevent unfair holes.

Floors, 24 in. deep in engine and boiler space, of $\frac{1}{2}$ in. plates, with angle-iron $4 \times 3 \times \frac{7}{16}$ in. on the top of every floor to run from 6 to 7 ft. up the turn of bilge. The floors in the fore and after holds to be 23 in. deep, $\frac{1}{2}$ in. thick, with angle-iron on top, $3\frac{1}{2} \times 2\frac{3}{4} \times \frac{3}{8}$ in. The floor plates to run 4 ft. in the turn of bilge on each side of frame, in one piece.

Keelsons, as may be required, and to suit the engineer's drawings.

Breasthooks.—To have five breasthooks, 10 ft. long by $\frac{1}{2}$ in. thick, secured to the frames with reverse angle-iron, and well riveted across bow.

Pillars in holds, between keelsons and beams, to be 4 in. in diameter amidships, tapering to 3 in. at the ends.

Bulkheads, Water-tight.—One in fore peak, one before the engines, one abaft the boilers, and one in after hold ; all to be $\frac{1}{2}$ in. plate, tapering to $\frac{1}{4}$ in. at top, the plate stiffened with 3 in. angle-irons, 2 ft. apart.

Beams.—Upper deck, of plate $10 \times \frac{1}{2}$ in., with two angle-irons on top $3\frac{1}{2} \times 3 \times \frac{7}{16}$ in.. Beams and knees to be all welded in one piece, except in engine and boiler space, where they will be in lengths, to allow the machinery to go into the vessel, and to have angle-iron $4 \times 3 \times \frac{1}{2}$ in. on each side of top edge, finished on lower edge with half-round iron $2\frac{1}{4} \times \frac{7}{8}$ in., or angle-iron, as may be required. Main or lower deck of $11 \times \frac{5}{8}$ in., with $4 \times 3 \times \frac{1}{2}$ in. angle-iron on top, and $3 \times 2\frac{3}{4}$ in. angle or half-round iron on lower edge, to form part of the knee with a semicircular plate. Beams and knees to be all welded in one piece. An angle-iron on each alternate frame for main and lower deck, with as many in the engine and boiler space as the position of the machinery will permit. To have an orlop deck, to allow of such accommodation for stores as may be required.

Stringers.—An angle-iron all round the gunwale 5×4 in. with a covering plate 26 in. by $\frac{1}{2}$ in. riveted to gunwale stringers and upper side of deck beam. The same in lower deck $26 \times \frac{1}{2}$ in., and a vertical plate riveted to the side frames, and angle-iron on top of deck beams. The main deck stringer to run through the engine room. On main and spar deck two longitudinal tie plates, riveted to the angle-iron on top of beams from end to end of the ship; on the main deck 2 ft. $\times \frac{1}{2}$ in., and on the spar deck $18 \times \frac{1}{2}$ in.

Riveting.—The vessel to be all double riveted, and all butts, straps, or plates, to overrun three strakes, to make tight and strong work.

*Iron Screw Steam Ship, for the General Screw Steam Shipping Company.**

Dimensions.—Length between perpendiculars, 280 ft.; length of keel for tonnage, 254 ft. $2\frac{3}{8}$ in.; breadth, extreme, 43 ft.; depth from top of floor, 31 ft. 6 in.; burthen, in tons, 2,500.

Keel, 4 in. thick and 9 inches deep, in the greatest lengths that can be forged, to be double riveted, and the holes to be drilled.

Stem, thick 4 in., broad 9 in.; the front of the knee to be forged into the same.

Stern Post, thick at the keel 4 in., at upper trace about 5 in., broad 9 in., the inner or foremost post to be forged, as the engineer may require.

Frames to be of angle-iron $6 \times 4\frac{1}{2} \times \frac{1}{2}$ in. in midships, and $5 \times 3\frac{1}{2} \times \frac{1}{2}$ in. thick forward and aft, placed a distance of 20 in. apart. To be double, or placed back to back throughout the engine-room, and as far forward and aft as the form of the body will allow.

Reversed Frames of angle-iron, $4 \times 3\frac{1}{2} \times \frac{7}{16}$ in., to be riveted to every frame throughout the engine room to every alternate frame forward and aft, for the purpose of securing longitudinal stringer.

Floors, deep, in the centre, 2 ft. to 2 ft. 2 in.; thick $\frac{5}{8}$ in.: length, about 36 ft. in midships, diminishing forward and aft to form of body.

The Floor Plate is to be inserted between every frame, and riveted to the same; to have two angle-irons riveted on the top

* It was from this specification that the *Golden Fleece* and other steamers of the same class were built.

edge of the floors, $4 \times 3\frac{1}{2}$ in., the length of the engine room forward and aft, a single angle-iron $4 \times 3\frac{1}{2}$ in.

Plates.—All double riveted.

Garboard, or First Strake next the keel, thick 1 in., flanged down the side of the keel sufficiently to admit of two rows of rivets.

Bottom Plate, up to the turn of the bilge, to be $\frac{3}{4}$ in., double riveted.

Bilge, up to the under edge of the wale, to be $\frac{11}{16}$ in., double riveted.

Wales, thick $\frac{13}{16}$ in., double riveted, two plates, deep 2 ft. 2 in. each.

Topsides, $\frac{9}{16}$ inch, double riveted.

Sheerstrake, $\frac{11}{16}$ in., the whole of the plates to be double riveted, from the keel to the sheerstrake, all the butts to be flush and double riveted, the holes to be well countersunk, all the plates to diminish in thickness $\frac{1}{8}$ of an inch forward and aft, except in the way of hawse holes and propeller shafts.

Keelsons, or Boiler Bearers.—Three in number, one in the middle line, and one on each side of the middle line, extending forward and aft as far as the body will allow. Each keelson to be composed of a plate $\frac{5}{8}$ in., with two angle-irons, to be riveted to the reverse frames, or as the engineer may require.

Engine Bearers.—As the engineer may require.

Longitudinal Stringers.—Three, one over upper or spar deck beams, composed of plate-iron 1 ft. 6 in. wide, $\frac{1}{2}$ in. thick, extending from stem to stern, and secured to the sides with an angle iron $4 \times 4\frac{1}{2}$ in., and uniting all the beams. Another stringer at the main deck, composed of plate iron 2 ft. 2 in. wide, and $\frac{1}{2}$ in. thick, uniting upon top of the beams. Another plate 2 ft. wide, $\frac{1}{2}$ in. thick, riveted against the reverse angle-irons with an angle-iron $5 \times 4\frac{1}{4}$ in., riveted to the reverse angle-irons and plates. A third stringer on the lower deck beams, the same as the main deck.

Breasthooks.—Four or five forward and aft, $\frac{5}{8}$ in. thick, and 12 or 13 feet long, secured to frames with $5 \times 3\frac{1}{2}$ in. angle-irons.

Iron Stanchions under Beams.—Under every beam as required, 4 in. in diameter.

Water-tight Bulkheads.—Two at each end of the engine room. These bulkheads to be strengthened by vertical angle-irons 3×3 in., running from the floor to the upper deck. One bulkhead at the fore part of the fore cabin, from keel to upper deck, and one or *two before this,* as may be required, from keel to lower deck ; also

two between the after engine room bulkhead and the stern post, running from the keel to the lower deck. Lower plates $\frac{1}{2}$ inch thick, diminishing to $\frac{1}{4}$ in. at the upper part, riveted to the frames, and strengthened by riveted angle-irons $3 \times 3\frac{1}{2}$ in. about 3 ft. apart, running from the floor to the deck, with cocks and spanners to each bulkhead.

Rudder.—Main spindle about 7 in. diameter, hung by four pintles, the head to be fitted with a yoke or tiller. To have a handsome double mahogany steering wheel with brass bindings, stanchions, blocks, and galvanised chains complete.

Beams.—Spar deck beams of iron $8 \times \frac{3}{8}$ in., with two angle-irons on the top edge $3 \times 2\frac{1}{2} \times \frac{3}{8}$ in., and finished with round iron on the lower edge.

Main and Lower Deck Beams of iron 12 in. deep by $\frac{1}{2}$ in. thick, with two angle-irons $3 \times 3\frac{1}{2}$ in. on the top edge, and finished on the lower edge, with round iron.

Vessel, to class 12 *years,* A1, *at Lloyd's ; as by Regulations dated July,* 1857, *and as shown in Plates X. to XIV.*

Dimensions.—Length between perpendiculars, 300 ft.; extreme breadth, 43 ft.; depth from base line to underside of gunwale amidships, $28\frac{1}{2}$ ft.; tonnage (builder's measurement), $2696\frac{7}{10}$ tons.

The vessel is to have a full poop and forecastle, with main and lower decks, and orlop beams in lower hold. Bulkheads and general arrangements to be in accordance with the drawings.

Keel to be best hammered scrap, $12 \times 3\frac{1}{4}$ in., welded into lengths as long as possible, say 50 ft.; and scarphs to be 2 ft. 3 in. long. Keel to have three rows of $1\frac{1}{4}$ in. rivets, and the holes to be rhymed out before the rivets are inserted.

Stem to be $12 \times 3\frac{1}{4}$ in. at the heel, and rounded off at the fore part. Above the level line the bar to be diminished, and made at the top $7 \times 2\frac{1}{2}$ in.; and the rivets to be reduced to 1 in.

Stern Post to be $12 \times 6\frac{1}{2}$ in.; to have solid eyes welded to it to receive the rudder pins. The inner stern post to have the same sectional area, and to be scarphed on to the rudder post and to the keel by scarphs 2 ft. 3 in. long. Both stem and stern posts to be best hammered scrap.

Plates to be placed alternately inside and outside; the horizontal and butt joints to be double riveted, the latter to be perfectly well fitted before the riveting is commenced. Garboard strake to be $\frac{17}{16}$ in.; from garboard strake to upper part of bilge, $\frac{16}{16}$ in.; sheer-strake, extending 15 in. above the main deck, $\frac{16}{16}$ in.; sheerstrake,

forward, $\frac{14}{16}$ in.; from bilge to sheerstrake, $\frac{14}{16}$ in.; poop and forecastle, $\frac{8}{16}$ in.; bulkheads, $\frac{8}{16}$ in.

Frames to be of angle-iron $6\frac{1}{4} \times 4 \times \frac{11}{16}$ in.; to be spaced every 18 inches with a reversed angle-iron $4\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in. to every frame as high as the main deck; above this, in the poop and forecastle, the single angle-iron only to be carried up. The filling pieces at the back of frames, at the alternate strakes, to be a bar the same width as the frames, and the same thickness as the plates; to be carefully fitted. Frames to be in as long lengths as possible, and where jointed to have a bar of the same dimensions 4 ft. long, placed back to back.

Floorings to be formed of plate-iron, $\frac{7}{8}$ in. thick, 2 ft. 6 in. deep over the keel; to be carried well up round the turn of the bilge, with angle-iron on the top $4\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in., running up above the bilge, and joining the reverse angle-iron on frames. Short pieces of angle-iron in addition on the top of the floorings in the way of the main keelsons, in order to connect it by four rivets to each floor.

Main Keelson to be box-formed, 2 ft. deep and 20 in. wide, and made of plates $\frac{7}{8}$ in. thick, and angle-iron $4 \times 4 \times \frac{5}{8}$ in.; to have bridge pieces made of plates and angle-iron the same strength as the keelson; two of these under each mast. This keelson to run throughout the ship, where not displaced by the engine sleeper or the screw tunnel.

Bilge and Sister Keelsons.—These to run on each side of the main keelson; one, at the quarter breadth, to cousist of a plate and four bars of angle-iron in the form of a double T; the plate to be $14 \times \frac{7}{8}$ in., and the angle-iron $4 \times 4 \times \frac{5}{8}$ in. The bilge keelsons to be formed of bulb-iron, $10 \times \frac{3}{4}$ in., secured to the floors by two bars of angle-iron, $4 \times 4 \times \frac{5}{8}$ in. Also two other keelsons, made of plates $\frac{7}{8}$ in. thick, let down between the floors and secured to them by angle-iron $3 \times 3 \times \frac{5}{8}$ in. These to act as wash-plates for the bilge water.

All keelsons to run as far forward and aft as the form of the ship will allow; and, where practicable, to pass through the bulkheads, which are to be made water-tight; but where this is not desirable or practicable, the keelsons are to be secured to the bulkheads by brackets.

Beams to be secured to every alternate frame; those for the poop and forecastle to be of angle-iron, $6 \times 3 \times \frac{1}{2}$ in.; those for the main and lower deck to be of bulb-iron, $10 \times \frac{7}{8}$ in., with two bars of angle-iron, $4 \times 3\frac{1}{2} \times \frac{7}{16}$ in., riveted to the upper edge. Beams in the lower hold to be formed of a plate $12 \times \frac{7}{8}$ in., and four bars of angle-iron $4 \times 4 \times \frac{5}{8}$ in., and attached to every fourth beam.

All beams to have knee pieces to secure them to the frames ; to be 30 in. deep, and to run 30 in. along the beam.

Gunwale.—Angle-iron to be $6\frac{1}{2} \times 5\frac{1}{2} \times \frac{5}{8}$ in., going entirely round the ship ; to be riveted to the top side of the deck beams, and to the side plates. From the poop to the forecastle a second plate, 15 in. deep and $\frac{1}{2}$ in. thick, to be riveted to the stringer plate by angle-iron $4 \times 4 \times \frac{3}{8}$ in., to run parallel to gunwale strake, and about 8 in. from it, so as to form a recess or box to receive the feet of the timber stanchions of the bulwarks. All the iron work to be made water-tight before the timber work is fitted to it.

Stringers.—These to consist of plates on the upper side of deck beams, to be riveted to them and to the angle-iron. For the poop and forecastle to be $18 \times \frac{1}{2}$ in.; main and lower deck, $30 \times \frac{7}{8}$ in. ; upper and lower sides of hold beams, $30 \times \frac{5}{8}$ in. The length of the strips for crossing the joints not to be less than the width of the plates. Stringer plates to be secured to the reverse angle-iron of frames by angle-iron $6\frac{1}{2} \times 5\frac{1}{2} \times \frac{5}{8}$ in., and by short pieces to the outer shell of vessel by angle-iron $4 \times 4 \times \frac{1}{2}$ in. ; except for the poop and forecastle, where the angle-iron is to be $3 \times 3 \times \frac{1}{2}$ in. On the main and lower deck beams, are to be stringers $15 \times \frac{7}{8}$ in. wide, one on each side of hatchway, and running the entire length of the ship ; to be riveted to each deck beam by four rivets.

Diagonal Ties also to be applied to the main deck, to run diagonally from one stringer to the other ; to which, and to the deck beams, they are to be riveted. To be placed every 15 ft. in the lengthways of the ship ; to be $6 \times \frac{1}{2}$ in. thick.

Stanchions, of round bar-iron, to be riveted to every alternate beam by two rivets at each end ; to be $3\frac{1}{2}$ in. diameter in the lower hold, and 3 in. on the lower deck.

Breast Plates and Crutches to be formed of plates $\frac{7}{8}$ in. thick, secured to the side frames ; to be placed as shown in the drawings. Plates XII. and XIII.

Bulkheads to be five in number ; to be $\frac{1}{2}$ in. thick, secured to the side of the ship by angle-iron $6 \times 4 \times \frac{5}{8}$ in. ; the long side next the shell, and to have two rows of rivets, each rivet to be not less than 4 in. apart ; or to be fitted between two bars of angle-iron, $4 \times 4 \times \frac{5}{8}$ in. ; also to have brackets, or knee plates, riveted horizontally against the ship's side, and to the bulkheads on the fore and after sides, alternately, near the middle of each plate. Lining pieces between the frames, and the outside plates in the way of the bulkheads, are to be plates extending in one piece from the fore side of the frames before the bulkheads, and to the aft side of frames abaft the bulkheads. The bulkheads to be stiffened by angle-

iron, $4\frac{1}{2}\times4\frac{1}{2}\times\frac{5}{8}$ in., placed vertically every 2 ft.; at the line of the deck, angle-iron $6\times3\times\frac{1}{2}$ in. to be secured to the plates on each side of the bulkheads, fitted between the ribs, and made to receive the ends of the deck planks. All bulkheads to be made perfectly water-tight.

Rudder to be formed so as to unship without going into dock. The stock to be 7 in. diameter at the upper part, and flattened out to 9×4 in., tapering down to 7×3 in. at the heel. To have a back frame and three ribs, to which the plates are riveted by two rows of rivets; plates to be $\frac{5}{8}$ in.

Rudder Truck to be made of $\frac{5}{8}$ in. plates.

Rivets to be of the best quality; to be regulated by the size of the plates; and to be divided according to Lloyd's regulations for iron ships.

"Australian," Screw Steam Ship, built by Messrs. J. and G. Thompson, in 1857, *for the European and Australian Royal Mail Company.*

Dimensions.—Length (C. H. measurement), $331\frac{7}{10}$ ft.; breadth, $42\frac{1}{10}$ ft.; depth, to main deck, $20\frac{8}{10}$ ft.; do., to spar deck, $29\frac{8}{10}$ ft.; height of poop, 8 ft. Gross tonnage, 2760; register, 1512; engine power, 700.

The "Australian" ran the measured distance between the Cloch and Cumbrae lights (16 nautical miles) in $57\frac{1}{2}$ minutes; speed, on Admiralty trial at Stokes' Bay, with 1,200 tons cargo, 14·575 knots per hour.

Keel, formed of three plates; centre plate, 45 in. broad by 1 in. thick; side plates, $12\times1\frac{1}{8}$ in.

Stern post, of hammered iron, in one piece; after post, 12×5 in.; inner post, 12×7 in.; lower post, 12×8 in.; with about 8 ft. of the keel forged on it.

Stem, of hammered iron, 14×4 in. at bottom; $12\times3\frac{1}{2}$ in. at top.

Frames, spaced 18 inches apart; to be of angle-iron, $6\times3\frac{1}{2}\times\frac{5}{8}$ in., made double in wake of engine and boiler space; reverse frames, $4\frac{1}{2}\times3\times\frac{1}{2}$ in., one on every frame, but double in wake of engine and boiler space.

Floors, of plates, 33 in. deep $\times\frac{5}{8}$ thick, carried up to turn of bilge, and joined to keel with angle-iron, $5\times3\times\frac{1}{2}$ in.; two bars of angle-iron placed alongside top edge of centre keelson, $5\times5\times\frac{5}{8}$ in., with plate $36\times\frac{5}{8}$ in. on top of same, running right fore-and-aft; also 'thwart ship plates, 9 ft. long $\times26\times\frac{3}{4}$ in., running

across fore-and-aft plate every 4 ft. 6 in., for the purpose of binding the floors and keelsons together.

Keelsons.—Two side keelsons, with plates riveted to the plating of vessel.

Plating.—Garboard strake fore-and-aft, $\frac{7}{8}$ in., midships, 1 in.; next strake, ditto, $\frac{3}{4}$ in., midships, $\frac{7}{8}$ in.; thence to bilge, ditto, $\frac{11}{16}$ in., midships, $\frac{3}{4}$ in.; thence to sheerstrake, ditto, $\frac{5}{8}$ in., midships, $\frac{7}{8}$ in.; sheerstrake, ditto, $\frac{7}{8}$ in., midships, 1 in.

All the plating, from keel to gunwale, lap jointed horizontally; vertical butts, all flush jointed.

Riveting.—Keel, stem, and stern, and all other plating double riveted; keel rivets, $1\frac{1}{4}$ diameter; remainder 1 in. to $\frac{7}{8}$ diameter.

Beams.—Main deck beams of bulb-iron, $10 \times \frac{5}{8}$ in.; upper and lower deck beams of bulb-iron, $9 \times \frac{1}{2}$ in.; with two bars angle-iron on upper edge, $3 \times 3 \times \frac{1}{2}$ in.

Stringers.—Upper deck, of plates, 42 in. broad $\times \frac{5}{8}$ in. thick, midships, $\frac{9}{16}$ in., at ends with angle-iron, $7 \times 4 \times \frac{3}{4}$ in.; main and lower deck beams, plates 36 in. broad $\times \frac{5}{8}$ in. thick; midships, $\frac{9}{16}$ in. at ends with angle-iron, $5 \times 3 \times \frac{5}{8}$ in.

Clamp plates, $18 \times \frac{5}{8}$ in., running the whole length of the vessel.

Deck trussing.—On the upper deck, on each side of the hatches, a plate $24 \times \frac{1}{2}$ in. carried right fore-and-aft; also between same on the stringer plates, two plates 30 in. broad $\times \frac{3}{8}$ thick on each side of the vessel, running right fore-and-aft; on main deck a plate, on each side of hatchways, $24 \times \frac{1}{2}$ in., running right fore-and-aft.

Hold stanchions, round iron, $3\frac{1}{2}$ in. lower hold; 3 in. between decks.

Bulkheads, of plates $\frac{1}{2}$ in. thick, stiffened with angle-iron, $4\frac{1}{2} \times 3 \times \frac{5}{8}$ in.

Iron Screw Steam Ship, "Himalaya," built by Messrs. J. Mare & Co., London, for the Peninsular and Oriental Company.

Dimensions.—Length of keel, 340 ft.; beam, $44\frac{4}{10}$ ft.; deep, $31\frac{4}{10}$ ft.; 3437 tons.

Keel, of bar-iron, 10×5 in. to be rabbited half the thickness of garboard strake into the keel, and the other half rounded over.

Stem, 10 in. broad at bottom by 5 in. thick, and checked same as keel to where the cutwater comes on the stem, and to be 8×4 in. at the top.

Stern Post, 10 in. broad and 5 in. thick, tapering to 10×4 in. at

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the spar deck, and a heel left on the after side to bear the rudder, with eyes for the pintles, turned so as to form a knee forward on the keel. The plate aft to run over the post, to form a place for the rudder.

Frames of angle-iron $7 \times 5 \times \frac{9}{16}$ in. for 120 ft. in midships, 20 in. from centre to centre, extreme fore-and-aft that, to taper to 21 in. $6 \times 4 \times \frac{1}{2}$ in.; 22 in. $5 \times 3\frac{1}{2} \times \frac{1}{2}$ in.; and 24 in. $4\frac{1}{2} \times 3\frac{1}{2} \times \frac{7}{16}$ in. The butt plates to fill up the space between the frames, so as to form a series of trussings throughout the body of the vessel. In engine and boiler space, and for ten frames before and abaft it, the frames to be doubled in the bottom, and a reverse angle-iron on every second frame from floor to gunwale $4 \times 3\frac{1}{2} \times \frac{1}{2}$ in. for the whole length of vessel, for fastening the ceilings to.

Plates.—Garboard strake for 150 feet in midships, $1\frac{1}{8}$ in. plates as broad as can be procured or worked; the remainder fore-and-aft to taper by $\frac{1}{16}$ in. to the extreme end to $\frac{13}{16}$ in.; bottom plates, to $\frac{7}{8}$ in. to the 6 ft. water-line for 160 ft. in midships, before and abaft this $\frac{3}{4}$ in. from the 6 feet water-line to gunwale $\frac{3}{4}$ in., except the upper plate 2 ft. 6 in. broad $\times \frac{7}{8}$ in. thick, to form the water-ways; all double riveted from keel to gunwale, and all butts to be flush; the upper strake to go to top of water-way. Spar-deck plates $\frac{5}{8}$ in. thick; all spaces formed by the projection of the plates to be fitted with liners, so as to avoid small pieces of rings being used. The butts to be perfectly close, as well as the seams, as no pieces will be allowed to be put and caulked over. The countersinking to be carefully done, and all the rivets to be full and smooth outside of plates, and to be chipped down while hot. The greatest care to be taken in the punching, to prevent unfair holes.

Floors, 22 in. deep in engine and boiler space, of $\frac{5}{8}$ in. plates, with angle-iron $4 \times 3\frac{1}{2} \times \frac{7}{16}$ in. on top of every floor, to run from 3 to 5 ft. up the turn of bilge, the floors in fore-and-aft hold to be 22 in. deep, $\frac{9}{16}$ in. thick, with angle-iron on top $4 \times 3 \times \frac{7}{16}$ in. The floor plates to run 4 ft. on the turn of bilge over each side of frame in one piece.

Keelsons.—The main keelson in midships to run the whole length of the vessel on top of the reverse angle-irons, and floors to be 16×18 in., and $\frac{5}{8}$ in. thick, the side keelsons to run as far fore-and-aft as the mould of the vessel will admit. Keelsons in engine room as required by engineer.

Breasthooks.—To have five breasthooks 11 ft. long, and $\frac{13}{16}$ in. thick, secured to frames by reverse angle-irons, and well riveted, and one crutch on fore and after peaks, to run square to the point of contact.

Pillars in holds, between keelsons and beam, 4 in. diameter.

Bulkheads to be water-tight, one in fore-peak, one before the engines, one aft the boiler, and one in after-hold, all to be $\frac{1}{2}$ in. plate, tapering to $\frac{3}{8}$ in. at top plate, stiffened with $4 \times 3\frac{1}{2}$ in. angle-iron, 3 feet 6 in. apart.

Beams.—For upper deck, plate, $9 \times \frac{1}{2}$ in., with two angle-irons on top, $3 \times 2\frac{1}{2} \times \frac{3}{8}$ in., and finished on lower side with angle-irons $2 \times 2\frac{1}{2}$ in. in the same manner as described for main and lower decks. Main deck, of plate, $12 \times \frac{5}{8}$ in. with 2 in. angle-irons on top, $4 \times 3\frac{1}{2} \times \frac{1}{2}$ in. Beams and knees to be all welded in one piece, except in engine and boiler space, where they will be in lengths, to allow the machinery to go down to the vessel, and to have angle-iron $4 \times 3\frac{1}{2} \times \frac{1}{2}$ in., on each side of top edge, finished on lower edge with $\frac{1}{2}$ in. round iron, or angle-iron, $3\frac{1}{2} \times 3 \times \frac{3}{8}$ in., to run over end of beam plate at least 3 ft., or as may be decided on. Lower deck, of $11 \times \frac{1}{2}$ in., with $4 \times 3\frac{1}{2} \times \frac{3}{8}$ in. angle-iron on top, and lower edge to be finished as main deck.

Stringers.—An angle-iron all round the gunwale, $6 \times 4\frac{1}{2} \times \frac{1}{2}$ in., with a covering-plate, $26 \times \frac{5}{8}$ in., riveted to gunwale and to upper side of deck beams, the same in main and lower decks, $26 \times \frac{5}{8}$ in. To have aft, five diagonal iron straps, $8 \times \frac{5}{8}$ in., riveted to the reverse angle-iron.

Riveting.—The vessel to be double riveted, and butt straps or plates to overrun strakes, to make tight and strong work.

Iron Barque, required by Messrs. Watson Brothers, of Liverpool.*

Dimensions.—Length of hull between perpendiculars 86 ft. beam 24 ft. ; depth of hold, 9 ft. 9 in. ; draught, 8 ft.

Quarter Deck, 25 ft. from stern post, with 2 ft. rise, to be built according to a model to be furnished to the contractor.

Stem Post to be formed of a bar $4 \times 1\frac{3}{4}$ in., to be kneed at the bottom, and scarphed on the keel.

Stern Post to be formed of a bar $4 \times 3 \times 2\frac{1}{2}$ in., to be kneed at the bottom, and scarphed on the keel. Stern and stem post to have two rows of rivets.

Keel to be made of the pattern rolled by the Oak Farm Company.

Plates to be best Staffordshire or Shropshire iron ; bottom plates for 40 ft. of midships, from keel to bilges, to be $\frac{1}{2}$ in. Bilges and

* The *Josephine*, built at Greenock, 1844, from my plans, and the first sailing ship, I believe, ever built on the Clyde.

the strake next the keel fore-and-aft to be $\frac{7}{16}$ in. Remainder of fore and centre part of vessel to be $\frac{3}{8}$ in. After part, above water-line, and bulwarks, $\frac{5}{16}$ in. All the plates to be clincher-fastened, and the vertical joints covered by a strip $\frac{1}{16}$ in. thicker than the plates.

Frames to be of the best angle-iron, and to be 18 in. asunder.

Floorings, for 40 ft. in midships to be formed by angle-iron, $3 \times 3 \times \frac{1}{2}$ in., with rivets not more than 5 in. asunder; to these are to be attached, $\frac{3}{8}$ in. strips 15 in. deep in midships, and on the top of these to be angle-iron $3 \times 3 \times \frac{3}{8}$ in., to secure the ceiling. At the fore and after ends the angle-iron and strips may be reduced $\frac{1}{8}$ of an inch in thickness.

Side Frames to be of angle-iron $3 \times 3 \times \frac{3}{8}$ in. in midships, and $\frac{5}{16}$ in. fore-and-aft; these are to overlap the floorings 3 ft. at the bilge. A reversed angle-iron $3 \times 3 \times \frac{1}{4}$ in. to be riveted to each alternate frame, the outer flanche of which is to have holes punched in it every 4 in.

Deck Beams to be 3 ft. asunder, and to be made of double angle-iron $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ in., having another piece $6 \times 2\frac{1}{2} \times \frac{1}{4}$ in. between them. Stanchions for the hold to be placed under each alternate beam, and to be round bars $2\frac{1}{4}$ in. diameter.

Breasthook of Iron, to be made by angle-iron $3 \times 3 \times \frac{3}{8}$ in., riveted to the shell between the frames, to which is to be riveted a horizontal plate $\frac{1}{2}$ in. thick; this to form part of the forecastle deck, the remainder of which is to be made of iron plate $\frac{1}{4}$ in. thick, stiffened on the under side by three bars of angle-iron.

Transom to be formed in the same manner, to consist of angle-iron $3 \times 3 \times \frac{3}{8}$ in., and an iron beam $9 \times \frac{1}{2}$ in., to be secured at the quarters by strong angle-plates.

Rudder Case to be of iron $\frac{3}{8}$ in. thick, to be riveted to the shell, and to extend up to the deck, to which it is to be strongly bolted.

Gunwale to be formed by a piece of angle-iron $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ in., on the horizontal flanche of which is to be riveted a plate of iron $18 \times \frac{5}{16}$ in., extending under the deck planks.

Main Bulwarks to be formed by carrying the side plates up 3 ft. 6 in. above main deck, to be supported at intervals of 4 ft. 6 in. by iron knees; on the top of the plates is to be riveted a bar of angle-iron $3 \times 3 \times \frac{1}{2}$ in. The whole to be clincher-built and double riveted.

Keelson to be formed of a strip $9 \times \frac{1}{2}$ in., having four bars of angle-iron $3 \times 3 \times \frac{3}{8}$ in. riveted to it, to run on the top of the floorings, and to be riveted to them.

Bulkheads.—One at each end, as may be hereafter determined,

to be $\frac{3}{16}$ in. thick, stiffened by four bars of half-round iron $2 \times \frac{1}{2}$ in.

Two Tanks, to contain 12,000 gallons, to be made of $\frac{1}{4}$ in. plates, and to be fitted into the run of the vessel. The after-part of the vessel to have a false shell, forming a secret locker, with a secret entrance under the captain's cabin.

Rudder.—Rudder stock to be $3\frac{1}{2}$ in. diameter.

Iron Sailing Ship, "Deerslayer," built by Messrs. C. Tayleur & Co., at the Bank Quay Works, Warrington, 1854.

Dimensions.—Length between the perpendiculars 142 ft. 3 in.; breadth of beam 26 ft.; depth of hold, from underside of deck amidships to top of ceiling, 15 ft. 6 in.; height between decks (deck to deck), 6 ft. 6 in.; to have an elliptical stern; the draft to be furnished by the purchasers, and the model by the builder. The builders accepting the draft to be considered as confirming the dimensions, and the ship to be built accordingly.

Keel to be of the best hammered scrap-iron 8 in. deep, 2 in. thick, in not more than three lengths, jointed with 2 ft. 9 in. scarphs; riveted to a treble row of rivets below, and double above, of 1 in. diameter from end to end of garboard strake.

Stem.—Best hammered scrap-iron, 9 in., and 2 in. at the heel, and fore part rounded 8×2 in. at the load line, and $5 \times 1\frac{3}{4}$ in. at the upper end.

Stern Post.—Best hammered scrap-iron 8×2 in. at the heel, 6×3 in. at the lead line, and 5×3 in. at the top, and to have solid eyes welded on to it, or sufficient bands riveted to the skin and stern-post, and to project at the heel for rudder pivot to work in, and elbowed 4 ft. on the line of keel; the fastening on both stem and stern-posts to be the same as keel and garboard strake.

Plates.—Plates to overlap horizontally, butts to be flush, and the whole to be caulked inside and outside; garboard strake for 70 ft. midships to be $\frac{9}{16}$ in., ends to be $\frac{1}{2}$ in. First row of bottom plates ditto $\frac{1}{2}$ in., ends to be $\frac{7}{16}$ in., remainder of bottom to lower deck ditto, $\frac{7}{16}$ in., ends to be $\frac{3}{8}$ in. Bilge strake ditto $\frac{9}{16}$ in., ends to be $\frac{1}{2}$ in. Lower deck binding strake $\frac{1}{2}$ in., ends to be $\frac{7}{16}$ in. Top sides ditto $\frac{7}{16}$ in., ends to be $\frac{3}{8}$ in. Gunwale binding strake ditto $\frac{9}{16}$ in., end to be $\frac{1}{2}$ in. Plates in way of hawse holes or shrouds to be $\frac{1}{2}$ in. thick.

Frames to be rolled iron, $4 \times 3 \times 2 \times \frac{7}{16}$ in. for 70 ft. midships, 18 in. centre to centre, and forward and aft, $4 \times 3 \times 2 \times \frac{3}{8}$ in., where they are opened to 21 in. centre to centre; or the same to be made

of angle-iron, viz., for 70 ft. midships $4 \times 3 \times \frac{7}{16}$ in., and 18 in. apart, centre to centre, with reversed angle-iron on every other frame $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in. riveted to them, and short intervening frames at the beam ends, riveted to the angle-irons on the stringers. The ends $4 \times 3 \times \frac{3}{8}$ in. opening to 21 in. centre to centre, with reversed angle-irons, $2 \times 2 \times \frac{3}{8}$ in., the frames to be shut up in one length, if possible, if not to have good doubling pieces, same materials as the frames, and to be well secured together at the joinings, riveted to shell and frames.

Floorings to be of plate-iron on every other frame, extending well up to bilge 18 in. deep, $\times\ \frac{3}{8}$ in., the intermediate ones to have the same, but to extend on the bottom as far as an horizontal line could stop them, with an angle-iron on the top $2\frac{3}{4} \times 2\frac{3}{4} \times \frac{3}{8}$ in., main keelson to be 12 in. deep, composed of two rows of plates, $\frac{3}{8}$ in. thick, riveted to angle-irons 6×3 in. top and bottom, the lower side to be riveted on both flanges to every frame.

Beams.—The lower deck beams to be made of T iron, $6 \times 4 \times \frac{7}{16}$ in. thick, with a half-round beading on each bottom edge, to give a finish, &c. The upper deck the same, only to be $\frac{3}{8}$ in. thick, the ends to be turned well down, the sides to form a knee, the lower part to be riveted to the angle-irons; or to be made with angle-irons and plates of equal sectional area. The beams to be on each alternate frame.

Gunwale.—Outside binding angle-iron, $4 \times 3 \times \frac{1}{2}$ in., riveted, the whole length of ship, to beams, stringers, shell, and gunwale box-beams.

Gunwale Box-Beam, &c., to be of plates 1 ft. 3 in. deep, $\frac{5}{16}$ in. thick, with an angle-iron $3 \times 3 \times \frac{5}{16}$ in. on the bottom edges; the plates to be set so far apart as to suit the wood or iron stanchions.

Stringers.—Placed on their flat on top of beam ends, the lower deck to be 15 in. wide, $\frac{7}{16}$ in. thick, with an angle-iron riveted on the top $3 \times 3 \times \frac{7}{16}$ in., and to every frame and beam. The upper deck stringer to be 20 in. wide, $\frac{3}{8}$ in. thick, riveted to the angle-iron of box-beams, and gunwale angle-irons, and to the deck beams.

Beam Bracings.—To have two longitudinal plates running from one end of the ship to the other, 9 in. wide by $\frac{3}{8}$ in. thick, placed on the top of carlings of hatches, and riveted to them and to the beams where they cross.

Stanchions to be of round iron, $2\frac{1}{2}$ in. diameter for lower hold, and $2\frac{1}{4}$ in. for the upper ditto, placed under every beam and keelson, with proper feet and heads to secure them sufficiently.

Breastplate and Crutches.—As many as may be thought necessary.

Bulkheads.—To have two placed as purchasers may point out,

extending up to upper deck; to be made of $\frac{1}{4}$ in. plates, stiffened with vertical bars, $3 \times 3 \times \frac{5}{16}$ in., 3 ft. apart, well secured to the bearing keelsons and floorings.

Rudder and Frame to be 4 in. diameter at the throat, and there flattened out to 7×3 in., then tapering down 5×2 in. The heel to have a steel pin inserted to work on the stern post cap; the outer frame to taper 5×3 in. at top, 5×2 in. at heel, and $4 \times 1\frac{1}{2}$ in. at the outside edge. Cross bars of 4 in. wide welded on. The upper part of the rudder to be recessed, to receive $\frac{3}{8}$ in. plates, double riveted, flush jointed, and neatly finished.

Chain Plates of sufficient strength as shall be approved, riveted to the sides, and to have strong sound joints.

Channel Plates made as may be necessary, well seamed.

Side Lights.—Cut all holes, and fix to the sides all lights where required.

Rudder Trunk to be formed of $\frac{1}{2}$ in. plates, well secured to stern-post, shell, and deck, and to suit the rudder.

Rivets.—Best quality, full sized, to suit plates, countersunk outside, and where wanted, most particular attention must be given to the riveting and quality of the rivets.

Iron Sailing Vessel, "Philosopher," Classed A 1 for 12 years at Lloyd's. Built by Messrs. T. Vernon & Son.*

Dimensions.—To be 187 ft. long between perpendiculars, 34 ft. beam, and 22 ft. depth of hold, from top of floors to the top of under deck beams, amidships. Tonnage, O. M., $1024\frac{38}{94}$ tons.

General Description.—The vessel to have a full poop, extending about 40 feet from the stern post, for a cabin for the captain and officers, and a raised forecastle forward for the crew. To be rigged as a ship, and to have a 10 feet rake of stem, well rounded lines, and about 2 feet rise of floor at quarter breadth; to be built to Lloyd's printed rules, and of the strength and quality of materials specified therein for a vessel of this tonnage; to class A 1 for twelve years.

Keel, Stem and Stern Posts, to be of bar-iron, $8\frac{1}{2}$ in. deep, and 3 in. thick, in long lengths, with scarphs not less than 2 feet long.

Frames to be 16 in. apart throughout vessel, and made of $5 \times 3 \times \frac{1}{2}$ in. angle-iron, with reversed angle-iron $3\frac{1}{2} \times 3 \times \frac{7}{16}$ in. on every frame up to lower deck beams, and upon each alternate frame above.

* This vessel was built from regulations in force previous to July, 1857.

Plating.—The garboard strakes to be $\frac{7}{8}$ in. thick; from the garboard strakes to the bilges, and the sheerstrakes to be $\frac{11}{16}$ in. ditto; the bilge strakes to be $\frac{3}{4}$ in. ditto; from the bilge to sheerstrake, $\frac{5}{8}$ in. ditto; sides of poop, $\frac{5}{8}$ in. ditto; sides of the top-gallant forecastle $\frac{1}{2}$ in. ditto.

The sheerstrake to extend about 15 in. above the gunwale, for the purpose of having the wooden stanchions of the bulwarks bolted thereto.

Deck Beams, for main and lower decks, to be of Kennedy and Vernon's patent bulb-iron, $8\frac{1}{2}$ in. deep, and $\frac{5}{8}$ in. thick, fastened to every alternate side frame with angular knee-plates; beams for poop and forecastle deck to be bulb-iron, $7\frac{1}{2}$ in. deep. All beams to be pillared where practicable.

Deck Beam Ties.—An iron plate, 10 in. wide and $\frac{1}{2}$ in. thick, to be laid upon the deck beams fore-and-aft, on each side of the hatchways on the main deck.

Stringer Plates, on main deck, to be 24 in. wide, and $\frac{1}{2}$ in. thick, and on lower deck, 19 in. wide, and $\frac{5}{8}$ in. thick, to be secured with a bar of angle-iron, $5 \times 4\frac{1}{2} \times \frac{9}{16}$ in. all round the ship. On the main deck stringer plate there will be a plate about 15 in. deep, set up on edge, and running parallel with the sheerstrake from front of poop to the forecastle, thereby to form a groove of 8 in. wide, to receive the wood stanchions for bulwarks, and in which they will be secured by bolts passing through and through in the wake of the poop and forecastle; this plate will join up to the reversed angle-irons on side frames, and be riveted to them; it will be secured down to the stringer plates by a bar of 3 in. angle-iron, and will be finished on the top edge by a piece of half-round iron, facing towards the deck of the ship.

Floor Plates.—One to be fastened to each frame, 22 in. deep, and $\frac{5}{8}$ in. thick, with a bar of $3\frac{1}{2} \times 3 \times \frac{7}{16}$ in. angle-iron on top edge.

Centre Keelson to be of the box form, 12 in. wide, and 15 in. deep, the two bottom angle-irons to be $5 \times 4\frac{1}{2} \times \frac{9}{16}$ in., and the two top angle-irons to be $3 \times 3 \times \frac{1}{2}$ in. Plating on the sides to be $\frac{1}{2}$ in., and $\frac{5}{8}$ in. on the top.

Bridge Keelsons.—One on each side of centre keelson, made of $\frac{9}{16}$ in. plates, let down between each floor, and secured to the tops of floors by a longitudinal bar of $5 \times 4\frac{1}{2} \times \frac{9}{16}$ in. angle-iron.

Clamp Plate, between main and lower deck beams, to be 19 in. wide, and $\frac{5}{8}$ in. thick, secured to reversed angle-iron on side frames.

Bilge Stringers to be formed of two bars of $5 \times 4\frac{1}{2} \times \frac{9}{16}$ in. angle-iron, riveted back to back, to be secured to reversed angle-iron at turn of bilge.

Bulkheads.—One to be fitted in the bow, and one in the stern, at a reasonable distance from the ends, to be made of $\frac{7}{16}$ in. plates, and stiffened by vertical bars of $3\frac{1}{2} \times 3 \times \frac{7}{16}$ in. angle-iron, placed 2 ft. 6 in. apart. The bulkheads to be attached to the shell by double frames.

Rudder to be made of a frame of wrought-iron, plated with $\frac{1}{2}$ in. plates. Rudder-head to be 5 in. diameter.

Joints.—Horizontal joints to be clincher-fastened with the tiers of plates outside and inside of each other alternately; the vertical joints to be flush, and covered with a strip of iron inside of the same thickness as the plating.

Rivets and Riveting throughout the vessel to be all executed in conformity with Lloyd's rules.

Iron Sailing Ship, "Lady Octavia," built at the Bank Quay Works, Warrington, by Messrs. C. Tayleur & Co.

Dimensions.—Length of keel on blocks, 190 ft.; fore rake to have a fine long clipper bow, but to be considered as equal to 10 ft. only; the rake of stern post to be 3 ft.; beam, outside, for one half the length in midships, not to average more than 35 ft.; depth of hold, from underside of deck to the top of ceiling, 22 ft. 6 in.; sheer, about 2 ft., as per model; height between decks, 7 ft. 9 in.

Keel to be best hammered scrap-iron, 9 in. deep, 3 in. thick, welded in lengths as long as possible (50 ft.), and scarphed with 2 ft. 6 in. scarphs, riveted with a treble row of 1 in. diameter rivets, from end to end, to the garboard strake.

Stem.—Best hammered scrap-iron 12×3 in. at heel; $9 \times 2\frac{1}{2}$ in. at load line; $7 \times 2\frac{1}{2}$ in. at upper end.

Stern Post.—Best hammered scrap-iron 9×3 in. at heel; 7×4 in. at load line; 6×4 in. at top. Solid eyes welded on it, or sufficient bands riveted to the stern post, and to project at heel for rudder foot, and elbowed 4 ft. on the line of keel; the fastenings on both stem and stern-post to be same as keel and garboard strake.

Plates not to exceed 2 ft 6 in. wide, clincher-built or lapped, to receive double riveting fore-and-aft, and jumped vertical joints; garboard strake, for 100 ft. amidships, $\frac{7}{8}$ in., ends, $\frac{3}{4}$ in.; first row of bottom plates, ditto, $\frac{3}{4}$ in., ends, $\frac{11}{16}$ in.; remainder of bottom up above the bilge, ditto, $\frac{5}{8}$ in., ends, $\frac{9}{16}$ in.; strake at turn of bilge, 2 ft. 6 in. wide $\times$ $\frac{3}{4}$ in., ends, $\frac{11}{16}$ in.; top of bilge to lower deck, ditto, $\frac{9}{16}$ in., ends, $\frac{1}{2}$ in.; lower deck binding strake, 2 ft.

6 in. wide for 160 ft. amidships, $\frac{11}{16}$ in., ends, $\frac{5}{8}$ in.; top sides, for 100 ft. amidships, $\frac{1}{2}$ in., ends, $\frac{7}{16}$ in.; gunwale, or bending strake, 2 ft. 6 in. wide for 160 ft. amidships, $\frac{11}{16}$ in., ends, $\frac{5}{8}$ in. To be strengthened in the way of the channel and hawse pipes; to be of the best iron, free from flaws and cracks, and to be sound round each hole when punched; no filling in pieces in any of the seams or butts. Poop to be plated up with $\frac{3}{8}$ in. plates; forecastle to be plated with $\frac{3}{8}$ in. plates. Plates to overlap the stern post, so as to make a recess for rudder to work in.

Frames to be of angle-iron, $5 \times 3 \times \frac{5}{8}$ in., and spaced 15 in. for half length amidships, and the ends, $5 \times 3 \times \frac{1}{2}$ in., spaces at ends opening to 18 in., with reversed angle-iron, $3 \times 3 \times \frac{1}{2}$ in., for half length amidships, and $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2}$ in. for the ends, on every alternate frame throughout up to the top. The angle-iron on every other frame to extend up 5 ft. above floorings, in as great lengths as possible, and well secured at joinings; to have wedge pieces at back of frames where necessary. The frames of poop and forecastle to be $4 \times 3 \times \frac{3}{8}$ in., with reversed angle-iron $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in. to each alternate frame.

Floorings to be of plate-iron in every frame, 22 in. deep; in centre, $\frac{7}{16}$ in. thick; riveted to the frames, and carried well up round the turn of bilge, with an angle-iron on top, $3 \times 3 \times \frac{1}{2}$ in., running up above bilge, and joining reversed angle on frames.

Main Keelson to be box-shaped, 2 ft. 6 in. $\times$ 1 ft. 9 in. wide; plates, $\frac{3}{8}$ in. thick, stiffened inside by angle-iron for corners and connection to floorings, $3 \times 3 \times \frac{3}{8}$ in., well secured, and extra strengthened in wake of masts; to be made water-tight, and suitably finished for a water-tank, with wash plates.

Bilge Keelsons.—To have two on each side, say two formed of two plates $\frac{3}{8}$ in. thick, 10 in. deep, placed 4 in. apart, and an overlap of 4 in. at top, riveted together, and secured at the bottom by angle-irons, $3 \times 3 \times \frac{3}{8}$ in. to every flooring; and the other two formed of two angle-irons, $7\frac{1}{2} \times 4 \times \frac{3}{4}$ in., back to back, riveted together, and to every floor. All the keelson extending right fore-and-aft, and not broken at bulkheads, but the latter made to fit nicely round them.

Beams to be bulb-iron; the lower deck to be $9 \times \frac{1}{2}$ in. in centre; upper deck, $8 \times \frac{1}{2}$ in. ditto; poop deck, $6 \times \frac{3}{8}$ in. ditto; forecastle deck to be double angle-irons, back to back, $5 \times 3 \times \frac{3}{8}$ in.; and to have plates riveted to them so as to form ends, extending along the beam 18 in., and down the frames at the side 15 in., with angle-irons, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in., to secure same to frames, shelf-pieces, &c., and a half round iron on inside edge to make a finish

if required; all the beams to be placed on every third frame, with additional beam at break of poop and forecastle, and to have carlings where necessary, and all hatchways, partners, and openings framed with iron, same size as beams; extra beams on forecastle deck under anchors.

Gunwale.—Angle-iron, $5 \times 3 \times \frac{5}{8}$ in., riveted the whole length of the vessel to beams, stringer, and shell.

Stanchions.—Round iron in lower hold, 3 in. in diameter; in 'tween decks, $2\frac{3}{4}$ in.; in poophouse and forecastle as purchasers may wish; placed under every beam, and riveted to them; the strength continued round keelson to floorings.

Stringers placed on their flat on top of beam ends, the lower deck to be 21 in. wide and $\frac{5}{8}$ in. thick, and the upper deck to be $18 \times \frac{1}{2}$ in., and the poop and forecastle ones $15 \times \frac{3}{8}$ in., with angle-iron $4 \times 4 \times \frac{1}{2}$ in., riveted to every frame, stringer, and beam.

Breastplates and Crutches.—As many as purchasers may want forward and aft, to be 24 in. deep in throat, with arms 30 ft. long, and tapering to ends, the lower ones to be $\frac{9}{16}$ in. thick, and upper ones $\frac{1}{2}$ in., with suitable angle-irons.

Bulkheads.—To have four, placed as purchasers shall direct, extending up to lower deck, to be made of $\frac{5}{16}$ in. plates, stiffened with vertical bars, $3 \times 3 \times \frac{3}{8}$ in., 3 ft. apart, well secured to beams.

Rudder and frame, 6 in. diameter to the throat, and there flattened out to 9×4 in.; then tapering down to 7×3 in.; the keel to have a steel pin inserted, to work on the stern-post cap. The outer frame to taper 6×4 in. at top, 6×3 in. at heel, and 4×2 in. at the outside edge; cross-bars welded on, 4 in. wide; the upper part of the rudder to be recessed, to receive the $\frac{3}{8}$ in. plates, double riveted to the frame, clean, and flush finished.

Beam Bracings.—To have diagonal riders on the top of both upper and lower beams, 6 in. wide $\times$ $\frac{3}{8}$ in. thick, placed about 10 ft. apart, riveted to stringers and beams at crossings, and to be carried right fore-and-aft.

Chain Plates of sufficient strength, as shall be approved, riveted to the sides, and long enough to take hold of two plates, finishing through rails, and prepared to receive dead eyes.

Channels made as purchaser may direct, and well secured.

Ballast Ports, four; size as may be required, and fitted water-tight; substantially framed, hinged, and secured.

Rudder Trunk to be formed of $\frac{5}{8}$ in. plates, well secured to stern-post and hull.

Iron Sailing Ship "Sarah Palmer," 1462$\frac{83}{94}$ tons, O. M. Built at the Bank Quay Works, Warrington, by Messrs. C. Tayleur & Co.

Dimensions.—Length between the perpendiculars, 225½ ft.; beam extreme outside, 36½ ft.; depth of hold, from underside of deck to the top of ceiling amidships, 23 ft.; rake of stern post 3 ft.

Keel to be of best hammered scrap-iron, 9 in. deep, 3 in. thick, welded in lengths as long as possible, say 50 ft., and scarphed with 2 ft. 6 in. scarphs, riveted with a double row of 1⅛ in. rivets from end to end to the garboard strake.

Stem.—Best hammered scrap-iron, 12×3 in. at heel, $9 \times 2\frac{1}{2}$ in. at load line, $7 \times 2\frac{1}{2}$ upper end. Riveted with a double row of 1 in. rivets, the fore-part to be rounded.

Stern Post.—Best hammered scrap-iron, 9×3 in. at heel, 7×4 in. at load line, 6×4 in. at top; solid eyes to be welded on for rudder, to project at heel for rudder foot, with steel cap, and elbowed at least 6 ft. on the line of keel; the fastenings on both stem and stern post to be the same as keel and garboard strake, riveted same as stem.

Plates.—None to exceed 30 in. wide, lapped, the plates being alternately in and outside; horizontal and vertical joints to be double riveted. Garboard strake, for 120 ft. amidships, ⅞ in., ends, $\frac{13}{16}$ in.; first row of bottom plates, 120 ft. do. ¾ in., ends, $\frac{11}{16}$ in.; remainder of bottom up to turn of bilge, do. ⅝ in., ends, $\frac{9}{16}$ in.; two strakes at turn of bilge, do. ¾ in., ends, $\frac{11}{16}$ in.; one strake at turn of bilge next above, do. ⅝ in., ends, $\frac{9}{16}$ in.; top of bilge to lower deck, do. $\frac{9}{16}$ in., ends, ½ in.; lower deck binding strake, 2½ ft. wide for 180 ft. amidships, $\frac{11}{16}$ in., ends, ⅝ in.; top sides, ½ in. ends, ½ in.; gunwale or binding strake, 2½ ft. wide for 180 ft. amidships, $\frac{11}{16}$ in., ends, ⅝ in. To be strengthened in the way of the channel, and hawse pipes as the superintendent will point out; all plates to be best iron, free from flaws and cracks, and to be sound round each hole when punched; no filling in pieces in any of the seams or butts. Poop and forecastle to be plated up with ⅜ in. plates. Plates to overlap stern post, so as to make a recess for the rudder to work in. To be plated solid round mast-holes on all decks, with deep iron rings for masts to wedge against on all the decks they pass through.

Frames to be of angle-iron, $5 \times 3 \times \frac{5}{8}$ in. at centre to ½ in. at ends, and spaced 18 in. throughout, with reversed angle-iron, $3 \times 3 \times \frac{1}{2}$ in. on every alternate frame up to the top, the reversed frames on every intermediate frame, to be carried up to an average

5 ft. above the turn of the bilge, but to be shifted, say alternately, $2\frac{1}{2}$ ft. and $7\frac{1}{2}$ ft. above bilge, in as great lengths as possible, and well secured at the joinings ; to have filling pieces at back of frames for the alternate strakes. The frames for the poop and forecastle to be main frames carried up, and reversed frames on them alternately, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in. All the frames and reversed angle-irons to be either welded in one length up to the top, or secured at joinings by back pieces at least 4 ft. long and well riveted ; these joinings or back pieces to be put in independently of the frames or reverse angle-iron, as the case may be, passing and securing such joining.

Floorings to be of plate-iron in every frame, 24 in. deep in centre $\times \frac{7}{16}$ in. thick, riveted to frames, and carried well up round turn of bilge, with an angle-iron on top, $3 \times 3 \times \frac{1}{2}$ in. running up above bilge, and joining reverse angle-iron on frames, short pieces of angle-iron in addition on top of the all floors in way of keelsons, and in order to connect them by four rivets to each floor.

Main Keelson to be box-shaped, 2 ft. 6 in. deep, and 1 foot 9 in. wide, plates $\frac{5}{8}$ in. thick, stiffened inside as the superintendent may point out ; angle-iron for corners, $3 \times 3 \times \frac{5}{8}$ in., and for connection to floorings, $3 \times 3 \times \frac{1}{2}$ in. ; well secured, and extra strengthened in wake of masts ; to be water-tight, and suitably finished for a water-tank, with wash plates and man holes as may be wanted ; pipe leading to deck, with brass socket on deck. Keelson to be carried as far forward and aft as possible, and secured if necessary to ends.

Bilge Keelsons.—To have four, two formed of two plates, $\frac{5}{8}$ in. thick, 10 in. deep, placed on edge, 4 in. apart, and one overlap of 4 in. at top, riveted together, and secured at the bottom by angle-irons on each side, $3 \times 3 \times \frac{5}{8}$ in., to every flooring ; also two formed of two angle-irons, $7\frac{1}{2} \times 4 \times \frac{3}{4}$ in., back to back riveted together and to every floor ; all the keelsons extending right fore-and-aft, and not broken by bulkheads, but the latter made to fit water-tight round them.

Beams to be placed on every alternate frame, both in lower and upper deck, poop, and forecastle. The lower deck to be 9 in. deep $\times \frac{1}{2}$ in. in centre ; upper deck to be 8 in. deep $\times \frac{1}{2}$ in. do. ; poop deck to be 6 in. deep $\times \frac{3}{8}$ in. do. ; forecastle to be $5 \times 3 \times \frac{3}{8}$ in. ; double-angle irons back to back, to have plates riveted to them, so as to form ends extending along the beams 18 in., and down the sides 20 in. from top of the beams, and to have double angle-irons on top, for lower and upper deck, $3 \times 3 \times \frac{7}{16}$ in. wide, and for poop, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in., and to be carried down the corner

part of the beam arms; all beams furnished with two half-round irons, riveted to the lower edge; additional beams at the break of the poop and forecastle, and to have carlings where necessary, and all hatchways, partners, and openings to be framed with iron of the same size, make, and strength as the beams.

Gunwale.—Angle-iron, $5 \times 3 \times \frac{5}{8}$ in., riveted the whole length of the ship, and going entirely round her.

Gunwale Box-Beam, between poop and forecastle, to be made water-tight, to be formed of two $\frac{3}{8}$ in. plates, 15 in. deep, 7 or 8 in. apart, with an angle-iron outside, back to back to gunwale angle-iron, $5 \times 3 \times \frac{5}{8}$ in., and one inside on stringer-plate, $3 \times 3 \times \frac{1}{2}$ in.; the wooden stanchions to be fitted into the box, and bolted with two bolts in each end; the intermediate space filled up with wood, bedded with felt and caulked; the inner plate of the box-beam to be carried round the poop and forecastle together with the angle-iron.

Stringers placed on their flat on top of beams; lower deck to be 21 in. wide $\times \frac{5}{8}$ in.; upper deck to be 21 in. wide $\times \frac{1}{2}$ in.; poop and forecastle, 15 in. wide $\times \frac{3}{8}$ in. The lower deck beams to have in addition a stringer on edge, 18 in. deep $\times \frac{5}{8}$ in., to be riveted to every frame; a short piece of angle-iron to be placed on every alternate frame to receive this, and to be secured to flat stringers and beams, by an angle-iron, $4 \times 4 \times \frac{1}{2}$ in., riveted all along. The poop and forecastle to have angle-irons to secure stringers, $3 \times 3 \times \frac{1}{2}$ in.

Stanchions to be rod-iron in lower hold, $3\frac{1}{4}$ in. diameter; 'tween decks, 3 in. do.; in poop, forecastle, and house, as purchasers may wish; placed under every beam throughout ship, and riveted to them, and secured to box-keelson by two angle-irons across top, $5 \times 3 \times \frac{5}{8}$ in.

Breastplates and Crutches, as many as purchasers may want, forward and aft, to be 24 in. deep in the throat, with arms, 30 ft. long, and tapering to ends, the lower ones to be $\frac{9}{16}$ in. thick, and the upper ones $\frac{1}{2}$ in., with suitable angle-irons.

Bulkheads.—To be four in number, and water-tight, placed as purchasers shall direct, extending up to the lower deck, the forward ones to be $\frac{5}{16}$ in. plates, with vertical bars, $3 \times 3 \times \frac{3}{8}$ in., 2 ft. apart, extending up to main deck; the others to be $\frac{5}{16}$ in. plates, stiffened with vertical bars, $3 \times 3 \times \frac{3}{8}$ in., 3 feet apart, well secured to the beams.

Rudder.—Rudder and frame 7 in. diameter to the throat, and there flattened out to 9×4 in., then tapering down to 7×3 in.; the keel to have a steel pin inserted to work on the stern post

cap, the outer frame to taper 6×4 in. at top, 6×3 in. at heel, and 4×2 in. at the outside edge, cross bars welded on 4 in. wide; the upper part of the rudder to be recessed, to receive the $\frac{3}{8}$ in. plates, single riveted to the frame, clean and made flush as by the drawing to be furnished by the purchasers.

Beam Bracings.—To have diagonal riders on top of upper and lower beams, 6 in. wide $\times$ $\frac{3}{8}$ in. thick, placed about 10 ft. apart, riveted to stringers, beams, and to themselves at crossings, to be carried right fore-and-aft.

Chain Plates.—Chain plates of length and strength as shall be approved by purchasers, very securely riveted to the sides, and long enough to take hold of two plates, finishing through rails with extra stringers to receive dead eyes.

Channel Boards of hard wood; size, length, and to be fastened as purchasers will point out, with plate-iron knees to support them, with strong iron band round outside edge to protect from chafing.

Ballast or Cargo Ports.—To have four into 'tween decks, the size will be pointed out, substantially framed, hinged, and secured in the most approved manner.

Side Lights, for the 'tween decks, of brass to be found by owners, builders fitting them in.

Rudder Trunk to be formed of $\frac{5}{8}$ in. plates, well secured to stern post and shell, and about 22 in. diameter inside, with cap on lower part to make a finish.

Rivets to be the very best quality and full size, to suit plates, and to be placed as close as purchasers may point out: particular care must be paid to the riveting and the quality of the rivets.

SUPPLEMENT.

In the introduction to the Second Edition of this Work, the circumstances are related which induced one who has led an active business life to sit down, from time to time, to prepare the materials requisite for placing before the public the progressive development of a great and truly national source of industry. The effort necessary for even so small a work, done without any pecuniary return, required some self-denial; but the trouble has been amply repaid by the unexpected favour with which, for twenty-six years, these efforts have been rewarded.*

In the additions now made to the original work, first published when little was known of the system by the public at large, I have followed the same style which was then employed. I have written for practical men, who will best appreciate plain, sound information, and for the ship-owner, on whom scientific or even technical terms would be lost. Papers of a much more elaborate and technical character are to be found in the able contributions published by the Institution of Naval

* There was no intention originally to proceed beyond a simple lecture, at a scientific institution, on the Construction of Iron Ships; but being once committed to the subject, and receiving great encouragement, I have, at the request of the publishers, revised and added to the original small work, until it has grown to its present dimensions.

Architects, and in many other works written on different branches of the noble art of ship-building as a science; but few of these render much assistance to the practical builder or shipowner.

There is one peculiarity which renders the task now again resumed difficult. At a very early stage the principles of iron ship-building were determined. Iron plates, jointed by riveting, and supported by a framework composed of angle iron, stringer plates, and iron deck beams, was the mode of construction first adopted in all vessels above the size of canal boats; the same applications are still made, and it requires much discrimination to perceive, and more to point out, those features which in reality constitute that great and material progress, the results of which are everywhere to be seen.

Looking back to its progressive stages, we first find iron employed in the construction of canal boats, as far back as the last century, carrying the hot ashes from the iron smelting furnaces; steaming on their passage with a freight which too frequently burnt up the vitals of ordinary wooden vessels. We next see them employed on shallow rivers as lighters; after this, steam vessels of various forms were constructed, treading closely upon and ultimately treading out, the only mode of building conceivable when steam was first introduced, —viz., to build the hull of the vessel of wood.

A long and gallant struggle was made for the national emblem, the "*Wooden* Walls of Old England," but nature even was against it; the child, as it were, outgrew its clothes; the material in sufficient quantity for building ships of wood has long since almost disappeared from this island, and it is a question whether,

should that material be again required, we could even procure from other countries the supply we should now require for the marine of this kingdom.

But gradually the change has been made, and we even see the last stronghold for timber ships—the Navy, fairly breaking down and giving up the struggle so long maintained at a fearful, and as I think will be seen, an unnecessary cost to the country.

Without enlarging this work to an inconvenient size, I can only offer a few additional examples of iron vessels, not illustrated in the former editions,—viz., an improved class of steam vessel for our river and cross channel communications, where passengers are to be carried at high velocities, and with the utmost personal comfort; also some of the features introduced into the hulls of the new ships in H. M.'s Navy, and in the Transport service. For these I am indebted to the kindness of Mr. Reed, Chief Constructor to the Admiralty. I have not, however, treated on the subject of armour-plated ships further than is necessary to point out the great superiority of iron to timber for the construction of the hulls of such vessels.

In the merchant service the development of the system of iron ships has been gradual but uninterrupted. There is to be observed a continually increasing tendency to add to the length of ships, and a favourable example of this is given in Plate XXX. Very few, if any, steam vessels have been built of timber for many years for the merchant service, and by degrees the ship-yards in nearly all the ports profess to build and repair iron ships.

Lloyd's rules having also necessarily, during an interval of ten years, undergone revision, the changes in the new code are by permission inserted here.

There have also been added a few of the more recent machines, or as they are technically called, "Tools," employed in the different operations of ship building.

It must not be denied, however, that another system has been introduced, from which a fine fleet of excellent vessels has sprung, and which will maintain its ground for some time. The combination of wood and iron was not an unnatural result of the conflicting opinions that have necessarily arisen in a transition so extensive and so important as the one we are now considering; and that this should take place was extremely probable from the fact of one great objection having always existed, and being still severely felt in iron ships, and which the partial employment of timber tends to obviate.

The old enemy to iron,—the adhesion of animal and vegetable matter to the outer shell, popularly termed *fouling*, has remained unsubdued. For thirty years at least, every nerve has been strained to remove the evil; science has exhausted its resources, and practical men have availed themselves of every suggestion that promised a remedy, but very slight progress has been made. Some palliation is experienced from the fact that iron ships, in situations where fouling is most observed, are not allowed to remain long at rest, while graving docks and slips are multiplied in all parts of the world, so that with a large proportion of our iron ships the objection is much reduced. There are, however, other vessels, and these generally sailing vessels, which are required to remain for long periods where they cannot easily be cleansed; so that wooden vessels that may be coppered, are still employed. Thence has sprung up the system above alluded to, by which wood

and iron are combined, and the ships thus built have received the general appellation of "composite" ships.

Several patents have been, during the last twenty years, taken out for building ships with iron framework, covered with planks; these have been caulked and coppered, similarly to ships built entirely of wood. The most successful builder under this system, was Mr. Jordan, of Liverpool, whose patent ran out and was renewed a few years since.

Allusion is here made to this system for two reasons; first, because the frames and a large portion of the vessel are made of the same description of iron, and are put together nearly in the same manner as in the ordinary iron ship; and secondly, because it forms a powerful argument in favour of the only method which has yet appeared feasible for preserving them for any length of time from their only remaining defect, the tendency to foul.

As this question may have an important bearing on the progress of iron ships, I will draw attention to its present position.

Having for several years witnessed the unfavourable effects as regards iron ships in the prevalence of this great evil, and perceiving that nothing but copper sheathing gave any prospect of a successful remedy, I proposed and patented a system of sheathing the vessels with wood, to which copper might be attached by nails, in the usual manner. These plans are described in the earlier part of this work, and therefore need no fresh description, further than to state generally what has occurred since their first publication.

It will be readily seen that the condition of the iron ships thus sheathed, resembles in many respects the

composite ship. The latter, as above stated, has a frame composed of iron; this frame is constructed with angle iron ribs, and several ribbon plates and diagonal tie-plates. To this frame is secured, by bolts and nuts, the timber planking. These bolts were at first made of iron, and great care was taken to prevent communication between them and the copper sheathing, but without success. The two first ships built by Mr. Jordan were examined, after having been about ten years at work, when the bolts were found much corroded, but the framework was pronounced perfectly sound. Again, when several more years had elapsed, one of these vessels was reported to be in excellent preservation as regards the frames and plates. We have here all the conditions to be found in an iron ship similarly sheathed with wood, and coppered, as designed by me, with one exception. In the composite ships the *bolts* alone suffered, and it is therefore evidently desirable, if possible, to avoid bolts.

This may be effected by making an external, as well as internal, frame of iron, the former being so shaped that, without the use of bolts, sheathing could be firmly attached to the ship, and thus a foundation laid for the planking required in coppering a ship. I had frequently called the attention of Government to this subject, without success, when circumstances occurred which gave some hopes that a trial would be made.

A committee, of which Sir John D. Hay, R.N., one of the Lords of the Admiralty, was Chairman, had been for some time inquiring into all matters connected with iron ships and iron armour-plating, when these plans were brought before them. From this committee were sent strong recommendations to the Admiralty

that they should be tried, as promising important results to the Navy, and the subject was more than once brought before Parliament. Fresh opposition, however, sprang up, and thus another delay of some years occurred. The reasons for this adverse step were never given, but I repeat what I then stated, that the decision not to test the principle was short-sighted, and this is best proved by the fact that after immense sums have been expended in creating a wooden Navy, two large iron steamers are now being built, to be sheathed with wood and copper, nearly similar to what has been so long recommended, but having one defect which it would be well if possible to avoid,—viz., that of fastening the wood sheathing to the vessel's sides by *bolts*, instead of the much firmer and simpler plan by which bolts may be avoided altogether.

Should this question be settled favourably, it will open out a large field for iron ship-builders, as it will be the last blow to timber ships.

I speak of fouling as being the last great enemy to the introduction of iron ships, as I believe another objection, viz., corrosion of the plates, to be almost removed, it being simply a question of care. A cement made of three parts sand and one part Portland cement, put on when the plates are dry, is a complete protection to the bottom on the inside, and careful painting is an equally good preservative for the rest of the ship.

America at no remote period had absorbed so large a portion of the ship-building trade of this country, and of Europe, owing to the facility of getting timber, that except for the purposes of repairs, our builders were fast losing their business. It was, however, easy to see that, should iron supersede wood, the tide must turn

in favour of this country. So it has been, and the universal complaint in America now is, that their building yards are deserted as regards the mercantile marine. As a proof of the difficulty of competing with this country, when iron is the material to be used, one fact only need be mentioned. Railway iron is sent from this country, paying large duties, to supply the Pennsylvanian Railway, and is laid down over some of the finest iron beds in the world, the cost of production there being so great that we can command the preference.

A few more remarks relative to ships of war may be applicable here. We have within the last twelve years spent enormous sums in producing a new fleet of wooden ships, and some of them have been armour-clad. We now hear complaints of the condition of these vessels, both from dry-rot, and also from the difficulty of making wooden structures to withstand the working of the engines, and the immense weight of the armour. It is proved that iron ships can stand these strains, besides being very durable, and it is not difficult to believe, from the experience we have in the merchant ships, that had the same money been expended in producing iron ships, no perceptible loss in that time would have occurred. All this is probably due to the short-sighted policy above complained of.

We now proceed to review several questions on which additional light has been thrown during the last few years.

Improved Materials for Building.

The quality of the iron with which ships are built is evidently one of primary importance, and not the less so from the fact that the outward appearance gives but

slight indications by which to judge of its merits. Trade-marks are by some surveyors insisted upon as a supposed guarantee for the quality, but this is evidently uncertain and unfair if carried too far. Old established houses will and often have presumed on their name to give bad material, and less known houses, however honest and however excellent their iron, are placed at a disadvantage.

A large quantity of iron has been made for ship-building which is avowedly of inferior quality, and to this the name of "boat" iron has been given as a stigma in regard to quality. The prejudicial system of determining the class of vessels by the quantity or weight of iron they contain evidently fosters this most serious evil. The thickness of iron is not the only requirement to be noticed by surveyors; but in practice it is certainly the first, and, being the most easily checked, is very often the principal point attended to, and the quality, being the most difficult to detect, is the least frequently called in question. Now, as excessive weight in a ship is a positive loss to the owners to the end of her career, it is a matter of astonishment that more decided measures have not been taken to insure a better material; and this will appear still stranger when it can be shown that, for the same strength, the cost of the ship is not necessarily increased with the improvement in the quality of the material.

The tests to be applied are those which show the tensile strength of the iron, combined with sufficient ductility. The ordinary plan is to take a portion of the plates to be used, and submit it to a tensile strain, and to bend it in a cold state. The tensile strength of iron plates for ship-building will range from about 14 tons

to the square inch up to 22 tons, while the difference of cost to the manufacturer in producing them will be probably as 8 to 10, so that for good iron the cost of the ship of *equal strength* will be positively less than one made of the lower quality. But this state of things, though it may be modified, will not be removed while the principal test of a ship is the thickness of the plates.

In reasoning on this subject we are led to the further inquiry, Is the strength of iron for ship-building to be confined even to the highest limit above named? It is well known that the tensile strength of iron may be much increased by a careful and more expensive process in its manufacture.

But a still larger question is now agitating the public mind. Every day is developing the fact that steel may be produced at a much lower price than formerly, and that it may contain those qualities which fit it for ship-building; that, instead of a tensile strength of only 20 to 22 tons to the square inch, as given by the very best iron, 35 to 40 tons is not an extreme test for steel which is so tempered as to be ductile and easily worked.

The process of its introduction, however, is slow, arising from a suspicion that the plates and bars will not be of an uniform quality, and that there is greater difficulty in working it. The last objection, however, is not well grounded; the principal point to be observed is that the plates or bars when heated are not raised to a temperature so great as that to which common iron may be subjected with safety.

Puddled steel was the material applied to the first steel vessel built under my own inspection. Both during construction and subsequently, the most perfect confidence was felt in the vessel by the builders and

the owners, and this was shown by the latter, after two years' experience, ordering another, which has been equally satisfactory. Several vessels have also been built of the steel made by Bessemer's process, and the makers claim for it superiority in tensile strength and ultimately in cheapness of production.

In the present state of our knowledge and experience it would be imprudent to venture any decided opinion upon the relative merits of rival systems, but it is a matter of great regret that the Government has not conducted a steady course of experiments for public use in a matter of truly national importance.

The ordinary process of steel-making, that by cementation, was first to reduce cast iron to malleable iron, and then to bury it in charcoal, in closed vessels, after which external heat was applied until the iron had absorbed sufficient carbon to produce steel. This process required seven to nine days, depending on the amount of carbon required in the steel. The cost of production was very great, and the use of steel for ships, boilers, engines, or machinery generally, has been very limited.

For the present object, I confine myself to a description of the peculiarities of puddled steel and that made by the Bessemer process, these alone having come into use for ship-building.

It may be as well to observe that there are these marked distinctions in the three kinds of iron known in commerce. The first, cast iron, containing carbon as an essential ingredient—say, on an average, 3½ per cent.; it contains silicon and other bodies, and melts, as stated by Professor Daniel, at 2,700 degrees Fahr.

Secondly, steel contains less carbon than cast iron,

but still it is an essential ingredient, varying from $\frac{1}{4}$ to $1\frac{1}{2}$ per cent. of carbon; it contains very little silicon or other impurities, and melts at 3,000 degrees Fahr.

Thirdly, malleable or bar iron is, in fact, pure iron, containing only a trace of carbon, $\frac{2}{10}$ to $\frac{6}{10}$ per cent., and melts at upwards of 3,000 degrees Fahr.

There are three methods of making steel; viz., by the puddling process, by that of cementation above described, and by the Bessemer process. In the first, the carbon in cast iron is so far reduced by working it in a puddling furnace that it becomes weldable.

In making steel by this process great care and experience are required to stop when the metal becomes weldable; this point can only be ascertained by practice, and even then it requires pure and good metal, containing at least $2\frac{1}{2}$ per cent. of carbon.

When the steel in the puddling furnaces becomes weldable it is made into balls, brought under the hammer, and the subsequent operations are the same as in making malleable iron; it may be treated in the same way, observing only that, because of the amount of carbon it contains (about 1 per cent.), it should not be heated to the same degree as iron.

There is not the least difficulty in rolling or forging puddled steel when made from a good metal; it is not a new invention, but is described in several scientific works, and has been regularly manufactured in small quantities for upwards of twenty-five years. It may be considered, when properly made, for strength, toughness, and rigidity, as standing between iron and cast steel.

The steel made by the Bessemer process has excited great attention, not only from the novel, scientific, and

very interesting methods adopted in producing it, but from the claim that it can be produced of a more uniform quality, and is capable of sustaining a higher tensile strain, than puddled steel.

The object in alluding to this subject is simply to give those who are interested some insight into the modes of manufacturing steel, and, generally, into its distinctive characteristics—a material that will probably, sooner or later, cause a great revolution in the construction of machinery and ships. I do not offer an opinion upon the rival claims to superiority; these must encounter the sure test of time. Now that so much has been done we may hope that other questions may arise to advance us a step further in the same direction: the most important being that we should be able to feel confidence in the power to manufacture the plates with a uniform quality.

The same question has arisen with regard to the quality of the rails required for our railways. In this case carefully trained inspectors are employed, who visit the iron works while the process of manufacturing is going on, and see to the quality and condition of every bar. Why should not our large shipbuilders inaugurate a similar system?

The invention of Mr. Bessemer has for its object the very desirable process of converting cast iron into steel almost direct from the smelting furnace. It has been above stated that while cast iron contains $3\frac{1}{2}$ per cent. of carbon, and while steel has from $\frac{1}{4}$ to $1\frac{1}{2}$ per cent., good malleable iron has no carbon. Now, as the degree of hardness in steel (the quality of the iron being the same) is in proportion to the amount of carbon, means must be taken to measure this quantity with great exactness, and this is done simply by expelling all the

carbon from the original pig iron, and then restoring the exact quantity required by means which admit of the amount being *measured.*

In the Bessemer process an air furnace or cupola is used to melt the iron, and when ready it is run into a large vessel called a converter, which is usually capable of containing 4 to 6 tons. This vessel is of an oblong form, not unlike a lemon; it has trunnions in the centre, like the oscillating cylinder of a steam engine; at the top end is a large mouthpiece, into which and from which the metal is poured; at the other is a perforated fire-brick, through which air from powerful air cylinders is forced. During the time that the iron is being received from the air furnace the converter is poised on its side, that the melted metal may not reach the perforated fire-brick, but when sufficient metal has been received, the blast is set on, the converter restored to its upright position, and the air is forced up through the liquid iron; the oxygen, in combination with the carbon, producing an intense heat and entirely expelling the latter. During the operation of consuming the carbon a bright flame is seen issuing from the mouth of the converter, but in 15 to 20 minutes this ceases, being a proof that it has been all expelled and the metal has become soft, malleable iron. To restore to it the exact measure of carbon to make steel of the required hardness, a given quantity of another kind of iron, heated in a separate furnace, and having a known percentage of carbon, is added, and the metal is then poured into a large ladle, and by ingenious machinery is conveyed to the moulds ranged round the pit, and each is filled. The blocks or ingots are cast of such sizes as are required for the plate or bar to be manufactured, and are at once taken to the rolls or hammer.

With the increase of carbon in steel the material is increased in tensile strength, but also in hardness, so that it becomes unfit for objects where ductility and toughness are required. It is always, therefore, considered desirable to employ a quality having only a small quantity of carbon. Steel has been so tempered and worked as to bear a tension of upwards of 100 tons to the square inch, and 50 to 60 tons is frequently attained; for boiler and ship plates, however, 35 to 40 tons is a safer limit. Even with steel of this quality care in working is necessary. It is for want of skill in working that many failures have arisen; no doubt these will give way before more advanced experience.

My own practice hitherto in steel vessels has been to allow two-thirds the thickness of iron plates, and with this allowance, the cost of small vessels has not been much increased; and if all be fulfilled that Mr. Bessemer foresees as regards the cheapness of production, structures of steel with the same strength will ultimately cost less than with iron.

It is much to be regretted that this important question has not been more extensively examined through the means of an impartial inquiry. Several private tests have been applied, but as the reports resulting from these have been contradictory, and have emanated from interested parties, the public generally are still in doubt and uncertainty; but since we have witnessed such high results, as regards increased strength, with a material that can be produced at a moderate cost—so ductile and well suited for the construction of boilers, ships, and many portions of machinery—the question becomes invested with an interest and importance demanding the gravest consideration.

Proportions of Vessels.

It has for many years been admitted that vessels of iron may be built much longer in proportion to their beam and depth than wooden vessels. Few builders have ventured with the latter to exceed six beams for the length, but with iron ships the proportions have been gradually increased till eight and nine beams for the length have been frequently adopted.

These proportions have, however, been entirely outstripped by some well-known vessels built by Messrs. Harland and Wolff, of Belfast, for the trade between England and the Mediterranean ports. The ships to which allusion is here made have been gradually increased in length till the proportions were attained of nearly eleven beams for the length. A drawing of one of these ships, the *Persian*, is given in Plate XXX., and the specification will be found at the end.

I have frequently made inquiries from the commanders as to their qualifications at sea, and have had but one reply—an unhesitating approval. This opinion is at variance with all preconceived views, and the question now arises, where will this stop?

It would not be in accordance with the object of this work to discuss this question in relation to the motion of the ship and the form of the waves, nor would it lead to any satisfactory result, seeing how numerous calculations worked out by the most elaborate theories are found to be entirely at fault in this field of inquiry. We must look alone to experiment, and thus far it is satisfactory. The only question then is this: should it be shown that increased length is not injurious to the sea qualities of the vessel, and that long ships are

worked with increased economy, can such ships be so constructed as to render them safe from straining, and if so, to what extend may the principle be carried.

So far as the experiment in this direction has been tried the indications are favourable. The *Persian* has been employed for about four years, crossing the Bay of Biscay in all weathers with deep loads, and giving no sign of weakness, or that the length is accompanied by any unfavourable symptom.

It does not necessarily follow that the increase of length requires any increase of the scantling at the ends. The additional strain is confined to the centre of the ship, and it is to this that attention must be directed. One object, however, must always be kept in view. As the length is increased the weight should be removed from the ends; heavy poops and forecastles are not admissible; while chain-lockers, water-tanks, windlasses, and all heavy weights, should be kept away from the extremities as much as possible.

Elasticity of Iron Ships.

No one with the least power of reflection dreams of making a perfectly rigid ship. All vessels must have more or less spring while labouring at sea. The amount of this elasticity is dependent on the strength of the ship and on the materials of which she is built. Frequent discussions have arisen as to the relative amount of yielding perceptible in a wooden ship and in an iron ship. It is probable that a wooden ship will bend more than an iron ship without being endangered. Should the bending of an iron ship be great in the direction of the plane of the plates, fractures in the seams must follow. It is desirable that the strength

should be so distributed that the spring of the ship may be uniform and not more in one place than in another. It is frequently observed that the weakest point in a body liable to strains is the *measure* of its strength, but this is not true in every sense if such strains are sudden and varying. The elasticity will more or less be centred in the weakest point, and the strength is found to be much less than is due to the sectional area of material at that point.

When these questions are to be applied to a ship or girder we must consider,—first, that when the weight is in the centre, the upper portion is compressed and the under portion is stretched; and secondly, when the weight is at the ends, the upper portion is stretched and the lower portions are compressed.

Mr. Barnaby, assistant-constructor of the Navy, has investigated this subject with much care, and has contributed a paper upon it to the Institution of Naval Architects. He says, "If a plate is brought under the action of a steady strain, it is a matter of indifference how many points of weakness there may be, and how much stronger the material may be, lying between the weak points. But when strains are suddenly applied, we have to consider not only the number of tons required to break the weakest section, but the amount which it would stretch before breaking. It is, in fact, the work done in producing a rupture, viz., the force applied, multiplied by the distance through which it acts, which is the true measure of the resistance to rupture."

To illustrate the principles here involved, he gives particulars of experiments made to test the strength of bolts made on a plan suggested by Major Palliser, for securing armour-plates.

Four bolts were taken, all made of the best selected scrap-iron, for the purpose of the experiment, and all of the same diameter, viz., $2\frac{1}{4}$ inches. Screw-threads were cut on the ends of these, and nuts fitted. The other ends were formed with heads, leaving a length of 21 inches between the heads and the nuts. The four bolts being thus as nearly alike in every respect as they could be made, two of them were reduced down on the anvil for a length of $4\frac{1}{2}$ inches, in the middle of their length, to a diameter of $1\frac{7}{8}$ inch, which was the same as that of the iron remaining within the screw threads. The other two bolts retained the full diameter throughout. They were broken in the hydraulic press with the following results, viz.: The bolts not reduced broke at the thread of the screw, at 63 and 69 tons respectively, or at 22·8 tons and 25 tons respectively per square inch. Those which were reduced broke at the reduced part, at 64 and $65\frac{1}{2}$ tons respectively, or at 38·33 tons and 31·58 respectively per square inch. The average elongation of the first two in 21 inches was inch, and of the last two, $1\frac{5}{16}$ inch.

The fact that the strains of greatest magnitude in a ship are sudden in their nature and of brief duration makes the principle under consideration one of no slight importance to naval architects, because we see that by its application we are able to increase the time during which a given force must be in operation in order to produce rupture.

This principle as relates to the iron deck of a ship is shown at Fig. 3, Plate XXI.; the method proposed by Mr. Barnaby.

It will be seen that, as the material is sometimes disposed at present, the plates are perforated in the lines of the beams, not only by the holes required for

the rivets to attach the plating to the beams, but by the deck bolts which secure the wooden deck lying on the iron plating. The loss from the iron punched out, and the weakening of that which remains, is very considerable. These lines of weakness occur at intervals of about 4 feet, and between them the plate has its full strength. The consequence of this is, that where the deck is put in tension, the stretching is confined to these weak places, and the amount of work which the whole combination is capable of doing before rupture is reduced.

In order to remedy this state of things the number of rivets for attaching the plating is reduced, and the bolts for securing the planks are kept at a distance from the beams. By these means a greater strength of plating is obtained across the lines of riveting. The next thing proposed is to reduce the strength of the plating between the beams to the same amount. This might be done by cutting holes in the plates; but Mr. Barnaby proposes instead to omit the butt-straps, and to arrange the plates so that in each of these spaces there shall be a continuous series of butts and plates in the proportion of one butt to every three plates. Reducing the material still further, he proposes to leave intervals between the butts, as shown in the drawing, so as to get spaces of uniform strength between the beams.

Mr. Barnaby claims several advantages in carrying out these principles, in the saving of weight and the increase of strength. He suggests new forms for the butt-straps, as shown in Plate XXI., Figs. 4, 5, 6, made with the view of reducing the loss of strength by the rivet holes to a minimum.

These questions lead to still more important ones; they open up an inquiry into the disposition of the

materials in the whole ship; and while drawing attention to it I may notice the care shown in the last ships designed by Mr. Reed, to dispose of the materials to the greatest advantage, by means of which a great reduction has been made in weight of the ships, without impairing their strength.—Illustrations of these are given in the Atlas of Plates.

Systems of Framing.

The best disposition of the materials of which a ship is composed must always be a leading question for the naval architect after the material itself has been determined upon.

That the outer shell shall be composed of flat plates, and the internal framework shall be a combination of angle bars and plates, seem at present to be points about which no questions are raised; by almost universal consent these are, and always have been, the forms of iron by which the great bulk of the iron vessels of all descriptions have been built; but the manner in which these shall be employed, so as to constitute the best adaptation of their strength, has always been matter of dispute.

The mode of jointing the plates has been fully described in the early part of this work, and no change has taken place since those remarks were written, but a much wider difference of opinion exists as to the best mode of arranging the framework. The three systems which have been principally advocated are:—

1st. The vertical frames, where every rib describes a transverse section of the ship.

2nd. The diagonal frames.

3rd. The longitudinal frames.

The system of placing the side frames diagonally, or at an angle to the base line of the ship, has been fairly tried, but has gained very few adherents. In the first development of iron ship-building this method was much advocated from the well-ascertained importance of it in wooden ships, where diagonal bracing and planking had shown decided advantages,—but it was not observed that the object for which this system was applied in wooden ships did not exist in iron ships, and therefore unless some other advantage was to be obtained, the inconvenience and additional expense of it need not be encountered.

With regard to other systems, however, the preference to be given to either is by no means so easy to determine. The transverse vertical frame is that most commonly adopted; by general consent all builders fell into this arrangement, principally, perhaps, because it was the plan generally adopted in wooden ships, and because it formed the most convenient framework to which to attach the plates. Therefore, without much inquiry as to the best disposal of the material, so as to secure the greatest strength with a given weight, the transverse frames only have come into general use in merchant ships.

Many excellent papers, to be found in the Transactions of the Institution of Naval Architects, have been written to explain the nature of the strains to which ships are exposed, and consequently the direction in which strength should be applied. All agree that both in the strains to be encountered and the application of strength, we must have in our minds an iron girder,—from this we should infer that the system which throws the greatest strength in a longitudinal direction, is that

which will constitute the best application of the materials; and supposing there were no other action to be provided in a ship except the strain in the direction of its length, the longitudinal system would have prevailed. But provision must be made for other requirements, and these tend to preserve the use of a considerable amount of transverse framework.

In the first place it is desirable to have a rigid frame which will stand erect while the process of plating is going forward, and to which the plating can be readily attached. Secondly, when completed, the framework should preserve the form of the outer shell, as in this the whole question rests; but in the ordinary ship the matter is not left to the outer plates and the transverse frames alone; every day we see additions of more efficient internal supports, consisting of keelsons, stringers, and even iron decks, all being horizontal and longitudinal fastenings. These, however, are generally so placed as not to interfere with the internal capacity of the ship.

We have not only to consider the ship as a large structure liable to meet strains incidental to her action while afloat, but we have also to provide for local concussions and for the effects of taking the ground on uneven and hard surfaces. These require that the structure, as a whole, should be strong, and that every part of the surface should be well backed up by internal framework. The usual transverse frames meet this question very fully, and are, I believe, absolutely essential for the greater bulk of our ships, if we desire to preserve them from dinging, and being both disfigured and weakened by the shell losing its correct form.

In speaking of the *vertical* system it will be seen that

a large amount of longitudinal framework is also introduced. In like manner, when speaking of *longitudinal* framing, we necessarily include a large amount of transverse frames. Now, to make the latter answer the object for which they are applied, namely, to diminish the weight by a better application of the materials, we are driven to make the frames less in number, and each frame of greater depth,—the intervals between each frame are, therefore, much greater, and the tendency to dinge from external pressure is much increased. This is no imaginary evil, but one which has much disfigured and injured vessels that take the ground, or which are exposed to a rough service.

There are, however, cases in which this system is successfully introduced; and I have been favoured by Mr. Reed with plans that enable me to exhibit this, and which will also afford an opportunity of illustrating the leading features of the application of iron in the construction of fighting ships, as now adopted in our Navy. (See Plates XXXIII., XXXIV.)

It is well known that the *Warrior*, under the administration of Sir John Pakington, as First Lord of the Admiralty, and of Mr. Watts, as Chief Constructor, was the first ship of her class in which the hull was built of iron. The framing of this vessel was placed vertically, having strong longitudinal keelsons and stringers secured to the outer shell between the transverse frames.

Mr. Reed has, however, adopted a different arrangement. In this the main frames are all horizontal, and the transverse frames are made subservient to the former, being composed of short pieces, the length equal to the space between the horizontal frames. But

to this arrangement is added an internal shell, as had been partially done in the *Warrior*, the distance between the inner and outer plates being the depth of the floors. This question corresponds with the water ballast tanks, now so frequently used in the merchant service, not only giving great additional strength, but also being a great protection in the event of the vessel striking the ground.

It will be readily seen that the space between the two shells must be large enough to admit the passage of men to clean and paint them. To do this in small vessels would occupy too much room, and make a serious reduction from the capacity of the holds; but in large vessels this objection does not prevail to the same extent.

The relative merits of the two systems of framing do not admit of a comparison in figures. The utmost we can do is to let experience and the exercise of sound judgment guide us.

The same remarks apply when adapting armour plates to iron-built ships, and when viewed in contrast to ships built of timber. The facility given in the former for constructing the sides to receive the armour, and the timber backing to support such great weights, will be made clearer by a careful inspection of the drawings than by the most elaborate written description.

Rivets and Riveting.

Attention has been drawn to the subject of rivets and riveting at p. 40 of this book, and it is only necessary here to add a few remarks. For this purpose I select

some passages from a paper contributed by me to the Institution of Naval Architects in 1862.

"The highest aim in naval construction is the employment of the least possible amount of material to attain the strength required; or the converse of this, viz., to attain the greatest possible strength with a given amount of material. This leads to three principal subjects for consideration.

"1. The scientific distribution of materials, combining sound theory with successful practice.

"2. The quality of materials to be employed; and

"3. The most perfect means for combining the several parts of which a ship is composed.

"I propose in this paper to deal with the last of these subjects, selecting two very important features of it—the *jointing* and *riveting* of the plates.

"In iron ship-building the system which has too frequently prevailed has been to fit the joints by rude means, bringing them as close as is thought necessary, and by the caulking tool to do the rest, which in many cases amounts to nothing more than the concealment of defects. The holes, also, are punched as nearly opposite to each other as is considered necessary and practicable, and a drift is supposed to set all right.

"The question of jointing, as the plates are now generally applied, has reference principally to the butt joints; the horizontal joints depending more on sound riveting than on accurate fitting.

"Now, as regards the butt joints, it is notorious that in no place do iron ships sooner show weakness than in these, and in no part of iron ship-building is the system so deficient. The method adopted in plating vessels is

to attach the plates to the frame of the ship in regular shear lines, commencing from the keel, if the vessel has one, and sometimes simultaneously at the shear strake, applying first those strakes that lie close, without lining pieces, to the frames. These plates, being previously punched, are brought together at the butts, and temporarily secured by bolts and nuts. To make the ends a tolerable fit, a hammer is generally used, knocking down the higher parts and throwing up a burr on one edge, as shown in Fig. 16, Plate VI.; but as this operation is very imperfect, the plates in reality only touch at points, as shown in Fig. 17, and even in what appears to the eye a good joint the plates often only touch at two or three points, perhaps for a quarter of an inch, or some very short length. In other cases, where still less care is observed, the joints will touch at one corner of the plates only, and be entirely separated from all the rest. The defects are quite visible as the work proceeds, but when the butt-strap is put on the light can no longer be seen through the joints, and thus observation is partially prevented. When the men are told of it, the reply is, that the riveting will stretch the plates and close the joints; but though this cannot be relied upon to any extent, to compensate for the width too frequently left, yet all questions are set at rest by the caulking tool—a flat chisel, which is passed over the joint—knocking down the burr which has before been raised, and closing the plates at the upper part of the joint, as shown in Fig. 18. This system makes the joint water-tight, but is so evidently defective in strength that no one ought to be satisfied with it. All parts not really in contact, *however slight* the separation may appear, are deprived

of the great additional strength which well-butted plates must afford.

"In the construction of well-made wrought iron bridges and girders these evils are avoided by the ends of the plates being planed; but when ship-builders are pressed to do the same the objection is raised that, as the joints cannot be parallel to each other, the difficulty and loss of time in taking the plates to the planing machine, one at a time, are so great that it will not pay. Besides which, the curved plates do not admit of being planed after they have been bent.

"While it may be admitted that some joints are very difficult to fit, even when planed, yet the greater number can be planed, and without any additional cost to the ship-builder, if his yard be well laid out, and proper means for carrying the plates are employed. Some few approve of, and have adopted, this system, but it is by no means general. It is, however, to urge its general adoption that I now take notice of it.

"But supposing that the two edges of the plate are made quite true, there is no certainty of their being brought and kept solidly in contact till the riveting is completed. The slightest motion will separate them, or the slightest projection will keep the joint open. Frequently the bolts put in temporarily to hold the plate in its position will move it, the holes in the frames to which it is attached not being fair with the holes in the plate itself.

"Thus we may infer that great pains should be taken to draw the plate endways and hold it there.

"The alternate strakes, those next the frames, being completed, the outer strakes are to be fitted; but these not only require the butts to be fitted, as before described,

but the holes have to be marked by the plates of the inner strakes, and then punched.

"Having made the edges true, and provided that the plates be kept closely in contact, I pass on to consider the question of the rivets.

"First, let us consider what is the effect of the rivets. They perform two offices; they are required to draw the plates, ribs, or butts together, and for this purpose the rivets should be strong and numerous enough to overcome any tendency these might have, from their lateral rigidity, to remain open or separate. Next, they are also required to resist the strains that come upon their sides and tend to sheer them in two. Now, in both these respects riveting may be imperfect; but it is to the latter we have to address ourselves with the greatest vigilance, as it is here that defects are most likely to arise, and most difficult to detect when they do arise.

"The usual practice is to punch all the holes in the under seam of plates to a template, observing always that the side from which the rivet is inserted is the lower side when under the press. This causes the slight taper, which punched holes always have, to be in the right direction for the insertion of the rivet.

"When the inner plates have been fitted, those for the outer strake are applied, and the exact position of each hole is marked by inserting through the inner plate a round plug previously dipped in some liquid whiting, or an elaborate and rather complicated template is made of these holes, by which the outer plate is punched. The plate being by either process thus prepared for punching, is taken to the press, and being lifted and guided by a gang of men, each hole is separately

punched. Any one who has watched this process with heavy plates knows how impossible it is to form the hole exactly where marked; and however careful the men may be, the holes, as a rule, are not fair with each other.

"The riveter now begins his work, and with the knowledge that the state of the holes is always such as above described, he is prepared with a steel drift, tapered at the point, but nearly parallel in the centre. This is violently driven into the hole by hammers, producing the effect shown in Fig. 19; swelling the holes in the plates, as at A, and leaving the vacancies at the opposite sides, as at B; or, to describe the case more accurately, the drift is forced rather into an oblique position, as shown by the lines C. He then inserts the rivet, as shown in Fig. 20, which is hammered up in the usual way. If the rivet be very hot, and the hole not very irregular, by dint of hard blows the hole is well filled and the work sound, though about this there is no certainty. But suppose the hole is very much distorted, the counter-sink half destroyed, and an abrupt angle at the centre caused by one plate partly overlapping the hole of the other, the effect is then such as is described in Fig. 21; the holes are not filled, and the rivet, when severely tested, becomes loose. There are, of course, all degrees of distortion; some so great that the head of the rivet will scarcely conceal the vacancy. I have frequently seen cases similar to that shown in Fig. 21. It is evident that wherever this vacancy occurs, however small it may be, the efficiency of the rivet is greatly reduced; and, supposing further (a case which occurs every day in our very best ships), that in the same seam both the rivets and joints have

the defects above described, how greatly must the general strength of the ship be diminished. To meet these defects large additions to the quantity of the iron have been made.

"That such a system is erroneous will be seen in what I believe to be the fact, viz., that nine-tenths of the imperfections which have appeared in new iron ships have arisen from ill-fitted joints and rivets. The inference to be drawn from this is, that we are increasing the cost and weight of the ship by an unnecessary quantity of iron, because we are unwilling to incur the needful expense in obtaining good workmanship. The same may be said as regards the quality of the materials, but this is not now our subject.

"I have stated that I consider it desirable to plane the edges of the plates to insure a sound joint at the butts; I will now proceed to throw out a few suggestions in the hope that improved methods of riveting may follow.

"I think it impossible that any good mechanic can rest satisfied with the rude system that has hitherto frequently prevailed, conducted upon principles that tend to perpetuate unsound work: too much depending upon the care of the workman, who always has the power of concealing his own bad work.

"The whole question of sound riveting evidently depends, in the first instance, on the form of the rivet-hole. In making the joints in engine work, as usually practised, and where care is bestowed in making the holes fair, one flange or plate is first drilled, and this is a guide for the tool in boring through the second. Now, if the same principle could be brought to bear in making the holes for the rivets in the plates of ships, the whole

would be reduced to a system that would ensure the soundest work in all cases, and give confidence in reducing the weight of iron; but in ship-building it has disadvantages that have not yet been overcome, and which do not so much result from the expense of the system as from other causes. First, the difficulty of getting the drill fairly opposite the hole at right angles to the plate, in the fine parts of the ship, and without which the hole will not be fair; secondly, the oil, if oil be used, and the borings getting between the plates, cause some trouble to clear them; and, thirdly, the burr that is formed on the edges of the plates in drilling requires another tool to remove it. I do not say that this system is impossible, though it is not apparently feasible; but, could it be carried out, it has such evident advantages that it is worthy the attentive consideration of ship-builders.

"In the meantime, and assuming that we cannot suggest anything better than punching, we must endeavour to counteract the existing objections as much as possible.

"First. To avoid a very common defect, viz., that the rivet heads are often the means of concealing a misfit in the rivet when not filling the hole, it has been suggested that the head of the rivet should be coned, and the holes countersunk on both sides, as shown in Fig. 22, so that such a defect could not exist without being seen; and the rivet in contracting would be drawn into its bed more firmly, instead of being loosened, as in the case of a parallel rivet. This will have some advantages; but the expense and time will probably more than counteract them.

"Secondly. It is recommended that the hole to be

countersunk should be rather smaller than the parallel hole, as in Fig 23, so that the drift, acting on the thin edge left at the lower part of the cone, will entirely remove any shoulder at the part where the plates meet.

"Thirdly. It is recommended that the rivets should be formed with a slight cone under the head, as in Fig. 24; and that while hot it should be set up by a heavy hammer from within by the holder up. This has long been the practice in some yards, but it is by no means general.

"Fourthly. It should be observed that sound riveting depends also on the care with which the two bodies to be united, whether plates or frames, are brought evenly and closely in contact, so that they may be tight without caulking. This operation, though not to be omitted, should be as light as possible; for it will be recollected that caulking, as practised in making the lapped joints in ships or boilers, tends to force the plates asunder, and thus rather weaken the joint than otherwise.

"The chief aim in jointing and riveting should be to arrive, as nearly as possible, at making the whole ship one great plate, as it is quite a mistake to suppose that lap joints or lining pieces are desirable, or that they add to the strength of the ship; the weight of iron used in these, if combined with the frames, would be much better disposed of. But, whatever system ultimately prevails, good workmanship in jointing and riveting should never be overlooked, and, if due regard is paid to it, and a reasonable value set on its merits, the reduction that may be made in the quantity of iron will amply make up for the difference."

Light Steamers for Passenger Traffic.

In this department of marine engineering, England appears to be lamentably behind America; and not only does this trait appear prominent as regards river navigation but also in some descriptions of coasting vessels.

In the American-built steamers plying between the United States and Europe, and in ships of war, the English type of vessel has been nearly always followed, until indeed all orthodox ideas were overturned by the introduction of armour-clad and turret ships into the Navy.

The primary cause of this distinguishing characteristic of American river and passenger steamers is, no doubt, to be found in the scope given to them in the noble rivers, so much surpassing in extent those of Europe.

In these a large field was opened to the bold and enterprising spirit of our cousins, and they have not neglected it. Their saloon-steamers, with the monster but inelegant "walking beam" of the steam engine surmounting the third or fourth story of these aquatic hotels, have long since obtained a wide fame, and notwithstanding the numerous and terrific accidents that have marked their career, are yearly growing in size and magnificence.

The hulls of these vessels are long shallow structures built of pine, with immense engine-beds and keelsons, which, with the addition of sundry trussings, form the base from which the enormous superstructure of machinery, paddle-boxes, and saloons take their rise. As experience gave confidence in those works, and the habits of the people had established them as a great national institution, a vessel of the same type, but with

a stronger and deeper hull, began to venture along the coasts. Thence sprang up several coasting lines, which, like the river steamers, have continued to increase in capacity and speed. A well-known and much frequented route of this description is maintained between New York and Boston, down the Long Island Sound, a voyage as trying as those generally undertaken by our cross-channel steamers. Travellers tell us that not only do these vessels carry some hundreds of passengers, accommodated in the most sumptuous manner, but that from their easy motion sea-sickness is almost unknown, and that in them most of the usual repugnance which landsmen feel to a voyage by sea is removed.

A better class of saloon steamers has lately been attempted on the Clyde, and on the Thames and Mersey, and superior vessels have for some time been employed in the mail service at Holyhead; but as a rule our river and cross-channel services are confined to small vessels, the accommodations of which are miserably in arrear of all other means of conveyance in civilised countries, greatly diminishing the number of passengers who would resort to our rivers as a source of pleasure, or be induced to turn their steps across the channel to travel abroad.

In the present work it is thought desirable to give illustrations of this class of vessel, beginning with the lightest river steamers, up to such vessels as are adapted to the channel and coasting trades. It will strike the intelligent reader that iron structures must be preferable to wood in this, as in most other descriptions of vessels.

The plans and specifications* here given relate only

* The specifications are inserted at the end.

to the hulls; the cabins, masts, and outfit, or superstructure, such as are seen in the American steamers, are omitted, as not generally required except in that country. It is not improbable that even there iron may be substituted for timber, but the present high price of iron and labour precludes its adoption.

We are not surprised to find that the employment of steel has been more general in this class than in any other, and all the examples given are of that material.

The first illustration is that of a small vessel (Plate XXV.), built by Messrs Money Wigram and Sons, in which the draught of water is reduced to 12 inches, to enable her to navigate the shallow portions of the River Euphrates. Fig. 1 is the longitudinal section; Fig. 2, the plan; Fig. 3, the transverse section at one of the paddle-boxes; Fig. 4, section amidships. To distribute the weight of the machinery uniformly over the whole structure, two sets of engines and four paddle-wheels were adopted, and every means were employed to ensure safety in a vessel of such extreme lightness.

Another example by the same builders (Plate XXVI.), and intended for the same river, is of heavier scantling. This vessel was designed to draw 2 feet 3 inches when light. Fig. 1 is the longitudinal section; Fig. 2, the plan; Fig. 3, the transverse section.

The next case (Plate XXVII.) is that of a vessel designed by myself, and built by Messrs Lewis and Stockwell, Iron Ship-builders, on the River Lea, near Blackwall. She was calculated to draw 3 feet 4 inches, when light, and has been employed for two years on the east coast, going through the worst weather of that severe navigation without showing the least symptoms of straining. Fig. 1 is the longitudinal section; Fig. 2, the sec-

tion through the paddle-boxes; and Fig. 3, the section at A B.

The last illustration of this light description of vessel is shown in Plates XXVIII. and XXIX. I designed this steam vessel to run from Dover to Calais, in connection with the South-Eastern Railway Company. Though from time to time various plans have been proposed to accomplish the same object, the difficulties in the way of adapting large vessels to many of the channel harbours, such as Calais, Boulogne, and Folkestone, seemed to be insurmountable. It was supposed they would draw too much water, and that they could not be turned in port. In the event of large vessels being used, it was thought essential that extensive works in the way of docks at each side should be made to receive them, where they could load and discharge their freight. To these plans were also added the proposal to run trains on to the decks of the steamers, rendering the removal of the passengers and luggage unnecessary. Some points, however, were overlooked in this matter. First, would the passengers remain in the carriages while thus conveyed on to the ship? Secondly, the weight of such a train, with the rails and beams to carry it, would add to the draft of water. And lastly, the same carriages could not run on the English and Continental lines, as the gauges of the rails are different. The objection that the draft of water of the vessel now proposed would be too great, is answered by the fact that it would draw no more than the present small steamers; and the second, that turning is rendered unnecessary by the double rudder, a plan which experience shows to be quite practicable.

The engines designed for this vessel are six hundred

nominal horse-power, to be worked to three thousand horses. This, it is expected, would, in consequence of the lightness, drive her twenty-three miles an hour, the distance between Dover and Calais. Such a vessel may have lofty saloons, reclining accommodation for two or three hundred people, or seats for three times that number, besides good refreshment rooms, and all those appliances for comfort which are freely offered on our railways, and so much more needed at sea.

Such a vessel also admits of the most complete system of longitudinal and transverse bulkheads, which, with a water-tight iron deck under the cabin, would render her free from all risk of sinking. The number of water-tight divisions as designed in this case amounts to nearly fifty.

Lloyd's Rules.

The rules issued by Lloyd's Committee for the Registry of British and Foreign Shipping in 1857 have been given at page 161, and it is now only considered necessary to add the Table G,* for the scantling of iron ships, as revised by the committee in 1865, which, with a few additional notices, gives the substance of the rules as they now stand. It must be observed that the large drawings attached to this work, Plates X. to XIV., were designed in accordance with the rules of 1857; the alterations from which, to comply with the rules of 1865, can be easily made by a reference to them.

The spacing of the frames has been increased from 18 inches to 21 inches, and in some instances 24 inches; and in the regulations for stringers and other longitudinal fastenings it is now directed that, in cases where

* See end of the volume.

ships exceed 14 depths or 7 breadths in length, the builders are to submit their plans to the Committee.

The quality of the iron is also taken into consideration in the rules; it is "to be capable of bearing a longitudinal strain of 20 tons to the square inch," and all plate, beam, and angle-iron to be legibly stamped in two places, with the manufacturer's trade-mark.

And, finally, the rules wisely abolish the system of classing for a term of years. The ship is to be classed according to her real condition, to be ascertained by periodical special surveys, and the different classes will be denoted by letters, thus, A_{A} A_{B} A_{C}. The two first are for those vessels which are built in accordance with the regulations, and the last for those which are considered entitled to an A class, but which have not been built in accordance with the rules.

Having taken an active part in urging that a change should be made in the system of classing by years, I may venture to refer here to other recommendations and alterations which I have advocated.

As Lloyd's Register is intended to be a guide to ship-owners and underwriters, it is desirable that *all vessels to be insured should be found in it.* This is not now the case; a large proportion of our finest steam-ships and many others are not classed, and so general is this that the book is no longer a guide to underwriters in such cases, and the character of the ship is to be guessed at, or obtained in an irregular and uncertain manner.

The remedies for this are, to use regulations merely as a general guide, and let each vessel be judged of according to its merits and the state of repair at the *time of survey*; also to have a much wider range in

the classification. This subject has been freely discussed in the Transactions of the Institution of Naval Architects.

BULKHEADS.

To this subject attention has been drawn at page 48 of this work. Ten years' additional experience has tended rather to increase than diminish the importance attached to it in the public estimation. It is only in ships of the largest size that longitudinal bulkheads can be introduced, and then only in the machinery department, where the side-holds are used as coal bunkers. The only limit, however, to the number of transverse bulkheads, consists in the arrangements on deck; each hold or division must have a hatch and should have a winch, thus each additional bulkhead causes an obstruction on the deck; but with this also arises an increased facility in loading and discharging. The nature of the trade and the convenience of the ship can alone determine these points, but it would be well if builders would invariably adopt the recommendation of the council of the Institution of Naval Architects, that no compartment should be so large but that if penetrated under water it would not endanger the safety of the ship.

I have in another place published the account of an accident which occurred to the *Sarah Sands*, one of the first iron screw steamers built for ocean navigation, in which I had paid particular attention to the bulkheads, a thing very unusual at that time. When taking troops to India a fire broke out in the after-cabin. The head of the ship was put to the wind, and the hose kept playing on the bulkhead. The fire raged with such fury that all the wood work was entirely consumed, the

beams bent down, and the magazine exploding, drove out the stern plates, giving free access to the water. In this state she rode out a severe gale, and in ten days delivered her whole living freight, of more than 400 persons, safe in Mauritius.

The mode of constructing bulkheads, as described in Lloyd's rules, is the one very generally adopted in large ships, and to this the reader is referred.

Hatchways.

The hatchways of iron ships are now almost always made of iron. In those for the cargo, where suitable covers and tarpaulins are used, the coamings consist generally of plates riveted to the beams, and rising 10 or 12 inches above the deck, having on their top edge a half-round bar riveted to them.

For those openings in the deck leading to the fire rooms, and covered by gratings simply to admit air, the sides are raised to three feet and upwards, so that the water on the deck cannot endanger the ship. In large vessels, however, it has become the practice to raise the coamings of the hatches over the engine-room and boilers to a height equal to that of the bulwarks; in other cases, to a level with the deck-houses, to be entered by side doors. The great facility which an iron ship gives for attaching these to the deck-beams, and thus making them part of the hull, cannot be too often insisted upon. There is probably no case recorded of a ship, in which these have been well constructed, foundering at sea by water entering through these openings. This cannot be said of ships with wooden coamings, however *well* secured.

Gunwales, Stringers, and Iron Decks.

A few additional plans for forming the gunwales of iron ships are given in Plate IV.A, Figs. 1, 2, 3. These drawings will best explain their construction, and it is only necessary to point out a few particulars. In Fig. 1 the stancheons for the bulwarks are of wood, and are let into iron sockets riveted to the iron gunwale. In Fig. 2 the bulwarks are of iron, and the stancheon consists of a round bar resting on the gunwale and supporting the rail. In Fig. 3 the side-frames are continued up to form the stancheons. It will also be observed that one strake of plates in Figs. 1, 2, are doubled, as is now usual in long vessels ; the doubling plates being generally required in the centre of the ship only, and for about half its length.

It is universally admitted that the system of framework of a ship which goes under the general term of stringers, has been sadly disproportioned to the strength of other parts of the ship. Supposing a ship to require some of the conditions of a girder, and the stringers of the upper decks to represent the upper flange, it would follow that their sectional area should be equal to the iron of which the bottom is composed, supposing no other action was to be provided for. This, however, is not the case, as the bottom has to sustain the whole weight of the vessel when taking the ground, but with this qualification it will be seen that the stringers, as generally made and as required by Lloyd's rules, must be much enlarged before any approach is made to the true and necessary proportions.

This question, like all similar ones in a ship, can only be regulated by experience. The whole of the upper-

deck should be made subservient to this object. To some extent the ordinary deck-planking adds strength, but before the development of the full strength of which an iron ship is capable can be attained, the deck, or a large portion of it, must be of iron ; this is now sometimes the practice, though in the great majority it is otherwise. The iron deck represents the upper-flange of the girder, and also fairly meets all the lateral strains which the deck ties, as given in Lloyd's rules, are intended to provide for, but it would be much strengthened by a system of fore and aft intercostal beams, say four or six in number. Without these, such plates, when subject to severe compression, would buckle, and their strength as a flange be considerably below what would be otherwise due to their sectional area.

Perhaps it will be argued that such a result has not taken place, but this reasoning should not be received, until it could be shown that with *an equal weight* of iron the greatest strength has been attained. This is peculiarly necessary in the case now under consideration, for it is well known that this portion of a ship has been generally made too light from the fear of adding weight so high up, and thus rendering the vessel crank; so that whatever the form of construction adopted, the material should be applied with scrupulous regard to its proper adaptation.

Attempts have been made to employ iron alone for the decks of ships, but this is probably not desirable, for iron being a good conductor of heat, two great evils have arisen. When the external atmosphere is high, the heat is too readily transmitted to the cabins and holds, and when the external atmosphere is low, the *vapour which* arises in the holds is rapidly condensed

against the iron plates, and falls back as water upon the cargo or into the cabins. It is probable, therefore, that iron decks sheathed with plank will prevail, especially in vessels of great length.

Beam Iron.

During the last few years great advance has been made in rolling beam iron for ships and girders for houses, and therefore now very generally superseding the beams made up of angle-iron and plates riveted together. Some of these are shown on Plate IV.A, Figs. 4, 5; the upper flange is the part to which the deck planks are secured. Fig. 6 is the form usually adapted to houses, but is also applicable to ships. A great variety of sizes have been rolled; iron makers seem to vie with each other in producing the largest and most perfect specimens, and have shown that there is scarcely any limit to these extraordinary productions.

Copper Sheathing.

The subject of copper sheathing for iron ships, as the only known remedy against fouling, has been noticed at p. 148 and in Plate XVIII., and allusion has also been made to it in the introduction to this Supplement.

I now proceed to describe an improvement on the former plan, by which facility is given for a better combination of the horizontal and vertical framing of the hull and for a less expensive system of shipbuilding.

In the ordinary mode of framing a ship, the vertical frames, as they cross the strakes of the shell, are only in contact with the alternate plates, and liners are interspersed to fill up the recesses caused by the outside plates. The stringers and keelson also are in general laid on the vertical ribs, and project into the vessel; or if both frames are brought into contact with the plates, one or the other must be formed in short pieces, reducing the strength and adding to the weight and expense.

There are two plans by which the work may be simplified. These are alike in one respect; in both the vertical frames are external and the horizontal frames internal. The *external* frames have already been described. These, while constituting the vertical ribs of the ship, are so formed as to allow of the inner wooden sheathing being attached without the aid of bolts. The *internal* frame may be horizontal, as above stated, and of any required strength or form.

Fig. 1, Plate XVIII.A, shows part of a ship's side, with the wood sheathing coppered. Fig. 2 is a horizontal section of the same.

Should the plating be made flush, as in Fig. 3, and T iron be used for the horizontal joints and frames, it is clear that all liners under the frames on either side would be rendered unnecessary; but by this plan the number of rivets would be much increased.

Fig. 4 is another plan, and shows the plates lapped in the usual way, with liners applied to the external frames. In this case the horizontal frames are of angle-iron, and the number of rivets much reduced.

Another method has, however, been preferred to any

of the above. This is exhibited in Figs. 6, 7. In this the internal ribs are vertical and the external ribs horizontal.

I have made a careful comparison of the relative weight of iron and number of rivets in the sides and bottoms of ships built on either of the above plans, allowing for the vessel that is to be sheathed a reduction of one-eighth in the thickness of the plates. Their relative position is represented by the following figures:—

	Weight of Plates.	Number of Rivets.
No. 1. A vessel not sheathed, and of the usual form	7·66	154
No. 2. Vessel sheathed as by Fig. 3 . .	6·49	216
No. 3. Do. Do. Fig. 4 . .	6·56	155
No. 4. Do. Do. Figs. 6 and 7	6·56	155

One more plan is given in Figs. 4, 5, to show the facility of applying a double bottom to a vessel in which the vertical frames are all external, and the internal frames horizontal.

I may repeat here an argument before used to show the grounds on which the success of this principle is based. Some years ago two vessels were built in Liverpool, since known by the name of composite ships. These were framed entirely of iron, having angle-iron ribs with ribbon and shear strakes of plates. Over these planks were laid, the same as in a timber-built ship, and then coppered. Both vessels went to India about fourteen years ago, and one, of about 700 tons, was sold to the East India Company. They have both been exposed to the most severe trials, and one a few years ago was wrecked, when the iron frame-

work and the plates were found to be in good condition; and, lastly, I have just heard of the second of these ships by a gentleman who saw her in the graving dock at Calcutta a few months since, and who states that the ironwork is still in good order.

Now the only exception to this good report was that, in both cases, the *bolts* by which the sheathing was secured had suffered from the copper, as might have been expected. It will be seen that the plans now described are designed to remove this only objection, and no bolts into or through the plates are necessary.

Floating Docks.

Iron has been extensively employed in the construction of floating docks—a subject so intimately connected with the object of this work, that to explain their construction I have availed myself of drawings kindly furnished me by Mr. G. B. Rennie of a large dock lately erected by his firm at Deptford for the Spanish Government, and now regularly at work at the port of Ferrol. Another, nearly similar, has been constructed by Messrs. Rennie for the Spanish port of Carthagena.

When ships were built of timber, all structures for raising or floating ships were also built of wood; but, with the introduction of iron for ship-building, a similar change would evidently follow in the construction of docks, and it is not perhaps too much to say that such a structure as is here described could not easily have been formed of timber.

It is not the intention to discuss the merits of different forms of floating docks; that which is chosen

for illustration is on the largest scale, is of simple form, has been put to work successfully, and very fully demonstrates the vast superiority of iron in the construction of large floating bodies.

The leading requisites in such a work are floating power and rigidity. How to obtain great stiffness with sufficient lightness is the problem to be solved. The dock now to be described combines the principle of a pontoon and a girder. As a pontoon, it has a horizontal floating surface of 36,000 square feet; as a girder, it has a depth of 50 feet.

The dock is represented in Plate XXXV., and may be thus described:—Fig. 1 is the plan; Figs. 2 and 3, the longitudinal sections; and Fig. 4, the transverse section on an enlarged scale.

The total length of the docks is 350 ft.; width, 105 ft.; and total depth, 50 ft. The base is 12 ft. 6 in. deep, making the sides above the base 37 ft. 6 in. The whole can be sunk within 2 ft. 6 in. of the top of the sides, and, allowing 5 ft. for the height of the blocks, gives a depth of water equal to 30 ft. for the vessel to float into its berth.

The whole weight of the ship and the dock must be borne up by the base alone. For this a floating power of 12,000 tons has been provided, and as the weight of the dock is about 5,000 tons, there is a surplus of 7,000 tons for lifting ships.

It is constructed in the following manner:—The base or pontoon is divided into two compartments by a water-tight bulkhead, E, running the whole length of the dock. Each of these compartments is subdivided into smaller ones by nine transverse bulkheads, *e*, forming ten water-tight chambers on each side. A longitudinal

bulkhead, K, not quite water-tight, is placed on each side of the centre, immediately under where the inside slope of the sides of the lateral compartment rests on the top of the basement. The side walls are also divided by a similar number of transverse bulkheads in continuation of the lower ones at E. The upper part of the side walls is composed of air-tight chambers, formed by a horizontal plate, F, and these chambers rather exceed a volume of water whose weight is equivalent to that of the dock when immersed. While these are kept tight, the dock cannot sink below a certain level. The base is again divided and strengthened by open lattice girders of an I form, of a length equal to the breadth, and of a depth equal to the depth of the pontoon. They are about five feet apart.

On commencing the work two of these girders were tested with a weight of 200 tons without any perceptible deflection.

The base is further strengthened longitudinally by a system of diagonal bracing. Thus there are, including the outside plating, nine elements of strength in a longitudinal direction to provide for any inequality of weight that may occur through irregularity in the keel or weight of the ship. The floor of the dock is covered with 3-inch teak planking, upon which, supported by every girder, is a solid teak beam, of about 20 in. deep $\times$ 15 in. wide, running from side to side. These beams support the keel-blocks and moveable bilge blocking-pieces, which have a rack and pall. On the middle of the intermediate girders the ordinary keel-blocks are fixed.

The arrangements for sinking, filling, and pumping out are as follows:—On either side of the dock, near

the centre, at the bottom, are two large sluices, G. These admit the water into a small reservoir or distributing chamber, H, from which wrought-iron pipes, 1 ft. 6 in. in diameter, lead one to each compartment. These pipes have sluices or cocks fitted to them, which are worked by hand from the top of the dock, so as to be always available and capable of regulation by the man in charge. The depth of water in each compartment is determined by an ordinary gauge. Four pumps are placed on each side, having 2 ft. 9 in. stroke, and 26 in. in diameter, and worked by a pair of high-pressure engines, with cylinders of 18 in. diameter and 2 ft. stroke of piston. The pumps are reduced in speed, in the proportion of 2 to 1, by means of gearing. Two powerful capstans and mooring bollards are fixed at each end of the dock for moving or mooring it.

The dock is worked as follows:—Suppose it empty, and the floor well above the level of the water, the sluices at the side are gradually opened and water allowed to flow into the different compartments. The dock will then commence sinking, care being taken by watching the gauges so to regulate the supply of water that it may sink uniformly and gradually. When the dock is sufficiently deep to take in the required vessel, the sluices are closed, the vessel hauled over the keel-blocks, and the breast and other shores applied, while the engines are set to work to pump the water out. Thus, for every ton of water pumped, one ton of the dock and ship is lifted. This operation is continued until the floor of the dock is well out of the water.

The time required for sinking the dock is about twenty minutes, and for raising it about three hours.

The following is a specification of the strength of the material used:—

The centre bulkhead E, Fig. 4, is made of plates $\frac{3}{8}$ in. thick, with 4 in. × 4 in. angle iron.

The transverse bulkheads, *e*, are of plates $\frac{3}{8}$ in. thick.

The longitudinal bulkheads, K, are plate iron $\frac{3}{8}$ in. thick.

The bottom, sides, and end of basement are made of plate iron $\frac{5}{8}$ in. thick.

The five lattice longitudinal girders consist of plates $\frac{5}{8}$ in. thick and 18 in. broad, fixed on the plates of the top and bottom of the basement, and forming butt plates, and a vertical plate 18 in. deep by $\frac{5}{8}$ in. thick. These plates are united by angle iron $3\frac{1}{2}$ in. × $3\frac{1}{2}$ in., one on each side of the vertical plate.

The transverse diagonal trussing and bracing consist of T iron $4\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{5}{8}$ in., crossed diagonally in two parallel rows, about 5 ft. apart from centre to centre.

These transverse girders and bulkheads are attached, top and bottom, by bars of angle iron 3 in. × 3 in. × $\frac{1}{2}$ in., placed about 2 ft. 6 in. apart, having the ends turned 10 in. or 12 in., and fixed to the plates of girders and bulkheads, as well as the plates forming the basement. Every sixth beam is carried down vertically, and united to the lower beam by angle iron of the same dimensions.

These frames are braced diagonally. The sides of the dock consist of iron plates, from $\frac{9}{16}$ in. to $\frac{3}{8}$ in. thick, and angle iron.

The system of diagonal framing is also carried up into the cellular chambers, and is composed of T iron 4 in. × 3 in. × $\frac{1}{2}$ in. and $3\frac{1}{2}$ in. × 3 in. × $\frac{3}{8}$ in., attached

to plates 9 in. by $\frac{7}{16}$ in. and $\frac{3}{8}$ in., riveted to the outside plating by angle iron $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × $\frac{3}{8}$ in. Gusset plates of the same thickness as the plates.

The outside plating of the sides is composed of plate iron $\frac{9}{16}$ in. and $\frac{7}{16}$ in., diminishing upwards to $\frac{3}{8}$ in.

The upper cellular compartments consist of vertical plates of iron $\frac{3}{8}$ in. thick, attached to the horizontal plates by means of angle iron $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × $\frac{3}{8}$ in.

On each side, in one of the floating chambers, a reservoir of fresh water is provided.

On the slope of the sides of the deck, at L, are placed steps composed of $\frac{1}{4}$ in. plate iron, joined by 2 in. × 2 in. × $\frac{1}{4}$ in. angle iron, for supporting the shores.

Three double rows of angle iron extend along the floor of the basement, and carry the longitudinal timbers on which the shores will rest.

Immediately above the slope there is a gallery, M, supported by angle-iron frames $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × $\frac{3}{8}$ in., about 5 ft. apart.

These frames are covered with $1\frac{1}{2}$ in. teak planking, fixed with screw bolts.

An iron handrail, of 1 in. diameter, and with vertical stanchions of wrought iron $1\frac{1}{2}$ in. × $1\frac{1}{2}$ in. A handrail of the same dimensions is fixed to the top of the side of the dock.

Double rows of angle iron, 4 in. × 4 in., are placed vertically on the outer side of each lateral compartment, at distances of 10 ft. apart, to carry vertical timbers, 8 in. broad, to serve as fenders.

The floating dock designed by Mr. F. I. Bramwell for the Danish island of St. Thomas, in the West Indies, is a modification of the same principle. The lower part is in form similar to that already described, and per-

forms the work of floating the whole structure with the ship to be lifted. The sides consist of large lattice girders, in each of which are three water-tight pontoons of plate iron. These floats are raised or depressed by large vertical screws, worked by steam-engines. Thus, suppose the dock being sunk to the required depth, and a ship placed on the blocks, the pumps are set to work, and as the dock rises, care is taken that the side floats should be lowered, or so regulated by the screws that they are kept about half immersed. It will be seen that the dock, as it rises, will always have a powerful agent on each side to keep it upright, or, should there exist any inequality in the balance of the dock, giving it a tendency to list over, the equilibrium may be adjusted by altering the relative position of the floats.

The leading dimensions of this dock are as follows:—Length, 300 ft.; external width, 100 ft.; inside of girders, 72 ft.; depth of bottom, 9 ft. 9 in.; extreme height, 42 ft. 3 in.; thus being able to lift a vessel drawing 24 ft., and weighing 4,000 tons.

The pontoon portion of this dock is made in six divisions; each of them can then be removed for repairs or cleaning.

It will only be necessary to describe one more form of dock. This is now being constructed by Messrs. Campbell and Johnson, of North Woolwich, for Bermuda, under the direction of the Admiralty. It differs from both the others in not being square at the bottom, but partaking more of the form of the vessel, and having caissons similar to dock-gates at each end.

It is proposed to build the dock complete where it *is, and launch* it broadside on, the naval authorities

being of opinion that it is capable of being towed out to Bermuda. This is a matter of great importance, as it obviates the necessity of a large establishment at that station, which would be requisite for the purpose of putting the dock together were it shipped in pieces from England, and avoids great delay and expense attending the completion of a dock of such magnitude abroad.

The main side is 333 ft. long, and it is 380 ft. long over all. Its width is 83 ft. 9 in. inside, and 123 ft. 9 in. outside the ironwork. The depth over all of the ironwork is 71 ft. 11 in. The total weight will be about 8,000 tons, and there will be nearly three million rivets used in its manufacture.

It is divided into forty-eight water-tight compartments, formed by seven longitudinal bulkheads and nine water-tight transverse main ribs.

The ends are curved, and form breakwaters, with the view to adapt her readily for her voyage across the Atlantic.

The longitudinal bulkheads, or main ribs, being made water-tight, form chambers that may be filled as required to trim the dock, or even to heel it over when the bottom requires repairs or cleaning.

When a ship has been taken into the dock, and the water partially pumped out, the caissons are placed in their position across the ends of the dock, and the water then enclosed is removed, and the ship becomes dry.

The Future of Iron Ship-building.

Writing at a time of great depression and of unexampled distress amongst ship-builders, the future becomes an object of anxious consideration.

Looking to the past, we cannot but regret that the old evil, so often repeated, has here been at work. Commercial prosperity—the result of railways, steam-navigation, and a greater freedom in trade, stimulated by the operations of banking, finance, and limited-liability companies—had led all classes to outstep the bounds of prudence, to create extensive operations, requiring an expenditure that could only be supported by the firmest *credit*. Credit, however, received a shock, over-production had to be paid for, orders were withheld, and the large manufactories, which were the producers, are now suffering. In all such cases it is observed that, at the time of the reverse, many contracts are in hand, and the contractors remain employed; but by degrees the work runs off, and a period of distress follows. Any improvement in trade is long before it reaches the contractors; and their operations, depending on accumulated capital—the result of profitable trade—and on public confidence, do not immediately feel the benefit of the revival.

In the present case, nearly two dreary years have passed over us with only slight signs of a restoration of confidence; the contracts have been worked off, and for a long time our engineering and ship-building concerns have been in a state of great depression, and many have been closed.

All this, however, has nothing to do with the fact that iron ships are fast superseding wooden ships, and the probability that this country will for many years keep the lead in their production. All countries are suffering as we are, and the only question is, are we *able to profit by the severe lesson which has been taught us?*—can we wisely in future keep within bounds,

and not be tempted to swell the means of production beyond what dull times are able to maintain? The unwillingness to let an order pass, though we may have already more on hand than can be executed within a reasonable time, is a snare into which many fall.

The present state of the building trade is therefore not to be taken as a criterion for the future. Within certain limits, it is probable we shall enjoy good employment for our ship-yards, and that England will long continue to build ships for her own commerce and for many other countries.

That France, Belgium, Sweden, and other iron-producing countries should compete with us for ships and machinery required for their own use is to be expected, but there are many others which will long continue to look to us for their supply.

One more question may have weight when considering this subject. Rapid progress has lately been made in reducing the cost of building and working steam-vessels, and there is a corresponding tendency to employ them in trades hitherto carried on by sailing ships. Large numbers of existing steam-vessels cannot enter upon this competition, and must give way to those which combine all the improvements that modern experience has shown to be practicable; and should fouling—the great enemy to the use of iron ships in warm climates—be removed, we may expect that a large and new field of operations in vessels for our own and for foreign countries will arise.

To all this we may add the hope that iron ships will soon be as exclusively adopted in the navy as they are *in the merchant* service.

MACHINES.

In the original work, p. 71, complaints are made of the little advantage taken by builders in applying machinery to the construction of such parts of the ship as admit of its adoption; but since then considerable progress has been made in this direction.

We find several eminent mechanists vieing with each other how to meet every requirement of the builder, —to punch, drill, and countersink the holes; to bend and straighten the plates, ribs, and beams; to cut and to plane them.

The machines in common use ten years ago were illustrated in the former editions of this work; others are now added. These are distinguished for their increased solidity, and, in some cases, in being worked by small engines attached to the frames.

One class of machines has not been included in these illustrations, viz., the multiple drill. This, as its name implies, is employed to drill a large number of holes at one time, and has been found valuable for girder or bridge work, but has not yet been successfully applied to any great extent in ship-building. The subject of drilling rivet holes has been alluded to in another place, and I am reminded of a discussion I lately heard, in which very eminent men gave opposite opinions—one advocating the punched hole, and the other that all holes should be drilled. Both were to a certain extent right; for ship-building, the system of punching seems to be the best, and, as a rule, the only practicable one; but for girders, where many plates are *of one size,* with the holes uniform throughout, drilling *is preferable.* The multiple drill then becomes ser-

viceable, and not only can many holes be drilled, but through several plates by the same operation. As many as sixty drills have been set in motion in one machine.

One great desideratum is not yet accomplished. We have seen no plan for riveting the ship except by manual labour. Machinery has been applied in making the plain parts of boilers and in girder work (see Plate XVI.), but great difficulties stand in the way with ships. The necessity for making the heads of the rivets on the outside of the vessel flush, and the impracticability of applying to both ends of the rivet that pressure which is necessary in the process of riveting, forbid the hope of success in this matter.

The great increase in the number of drawings beyond the original intention of the publishers only allows of the description of a few additional machines, and I have selected some that I have seen in operation, doing their work satisfactorily. Many others, equally good, and in many instances more elaborate, deserve the highest praise for the efficient manner in which they perform the various operations for which they are constructed.

Beam-bending Machine by Messrs. J. Bennie & Co., Glasgow, Plate XV. A.—This kind of machine is now very generally adopted, and is used when deck beams and other heavy framework require to be bent without being heated, and adds very much to the facility of this kind of work.

Fig. 1 is a plan, Fig. 2 is a side elevation. The framing, A, consists of a cast-iron table supported by legs at the four corners. This table is formed with strong guide-ribs projecting upwards and inclined

slightly inwards, and between these guide-ribs a sliding-block, B, works longitudinally, by means of which the bending or straightening is effected. Between the sliding-block, B, and one of the guide-ribs a fitting piece, C, is introduced, which can be adjusted by vertical and horizontal screws, and a cover plate, D, is bolted down over the whole. The sliding-block, B, acts on one side of the bar or frame which is being operated on, and at a point midway between two stationary but adjusting blocks, E, against which the bar or frame bears on its other side. A uniform travel is given to the middle block, B, by an eccentric or crank pin, F, while the degree of bending is determined, not by the travel of the middle block, B, as in common machines, but by the adjustment of the two side blocks, E, which are stationary during the bending. The arrangement of the driving gear may be varied, but, in the convenient modification shown, a large bevil wheel, fixed on a short vertical shaft, G, supported in a footstep bearing on the base plate, and on which is the eccentric or crank pin, F, for actuating the middle block, B, is driven by a bevil pinion, H, on a horizontal shaft, and this again is driven by spur gearing and the usual belt and pulleys. The eccentric-pin, F, is fitted with brasses, which are squared externally to work in a rectangular slot or opening, formed transversely in the middle sliding-block, B, to allow of the lateral play of the eccentric-pin. The sliding-block is formed or fitted with a projecting nose-piece, I, which may be of steel, to bear on the bar or beam operated on, and which rests on rollers, K K. The boxes, L, have cover plates, but only one is shown in Fig. 1, the other being removed. The blocks, E, are adjusted by means of hand wheels, M, which

work screws tapped through end pieces fixed to the blocks.

It will be readily seen that this machine also admits of being employed for punching, riveting, and shearing, by the application of proper punches and knives at the point N; but these operations are better performed by the machines specially adapted to them.

Independent Shearing, Punching, and Angle Iron Machine, by Messrs. Craig and Donald, of Glasgow, Plate XV. A.—This specimen will show the great advance made by machine-makers during the last ten years in the massive character of their work and the frequent use of separate engines for driving them, it being found much easier to bring the steam in a small pipe to the machine than, by shafts, wheels, and straps, to apply the power of an engine situated at some distance. There are also many other minor advantages in this system.

Fig. 3 is an end view, and Fig. 4 a side view, of the machine. A is the punch and the apparatus that contains it. B is the shearing-tool. C is the steam-cylinder giving motion to the shafts, D, which also give motion to the large wheel, E, and the shafts, F. G is an eccentric on the shafts, F, which is used to give motion to the lever, H. On this lever is the cutter employed to cut angle iron at the point I.

The Double-Lever Punching and Shearing Machine, made by Messrs. William Collier & Co., of Salford, performs several operations at the same time. At one end is the usual punching-press, at the other the shearing-tool. In the body of the machine are two sets of cutters —one for cutting ordinary angle iron, and the other for cutting T iron. It is driven by its own independent engine. It is unnecessary to describe the punching

and shearing process, as these are exactly similar to those of other machines already noticed; but the self-acting dividing table for the punching-press and the method of shearing angle and T iron have some novelty.

Fig. 1 is an end view of the machine and side view of the dividing table. Fig. 2 is a side view of the machine and end view of the dividing table. Fig. 3 is a plan of the dividing table. Fig. 4 is an elevation showing the manner of working. Fig. 5 is an end view of it. A is the motion required for moving the punch, B the motion for shearing. Both these are put into action by the shaft, C, by means of the levers, D F, shown in dotted lines. The same shaft, C, which gives motion to these levers, causes the cam, G, to revolve. On this is a stud which works the rod, H, giving motion to the peculiar-shaped shears, I.

On the left side, at K, the cutter for angle iron is secured. On the right side are two cutters. One of the latter, at L, in the downward motion cuts the upper part of the T, while the remainder is cut by M closing upon it sideways. A careful examination of the drawings will convey an idea of these operations much better than any description.

The dividing table is used to move forward the plates undergoing the operation of punching. The distance between the holes being exactly equal, it receives its motion from a cam, U, fixed on the main shaft, which, by means of a lever and a ratchet wheel, V (having four teeth), communicates with the reversing gear, W, in front of the bed. This motion drives the differential wheels at the end of the bed, by changing which the distance between the holes is varied.

For punching the outer plates of boilers it is necessary on two of the sides to allow for the circumference being increased when bent, and to punch the holes to a little coarser pitch.

This is effected by means of a tangent bar, N, one end being fixed upon a stud, O, inside the bed, the other end being secured at the end of the bed by means of a bolt and radiating slot, X, which is graduated so as to be easily set to any necessary amount of pitch required.

The nut in which revolves the screw for moving the table is fixed in a slide, P, underneath the table; attached to the nut is a bell-crank lever, R, the fulcrum, S, of which is also attached by a stud to the underside of the table. The other end of the lever carries a slide or shoe, T, which slides upon the tangent bar; thus, as the shoe slides upon the tangent bar the table is moved between each punch slightly in advance of the distance the pitch the screw would give it, and this in proportion to the angle at which the tangent bar is fixed. If it is left parallel with the table, the pitch given will be exactly in accordance with that given by the screw. The reversing gear in front of the bed enables the table to be worked both ways, or left standing, as the case may require, while fixing the plates.

Plate-planing Machine by Messrs. Shanks & Co., of Johnstone. Plate XVI. A.—This illustrates a system of much importance in iron ship-building. Although machines for this object are by no means new, yet they have only lately been acknowledged by the majority of builders as essential to good work. The rough system of fitting the butt joints, now happily fast disappearing, has been described under the heads of jointing

and riveting; this machine is more particularly intended to plane the ends of the plates for the butt-joints, and tends to promote a great improvement in plating.

A is the plate or plates on the table, B, to which they are secured by the screws fixed in the upper circular frame, C. When thus secured, the tool-carrier, D, is set in motion by the screw, E, and the plates are thus planed on the edge. The motion and tools employed are similar to those of the common planing-machine, except that in the latter the tool is generally stationary, and the work to be planed is moved.

SPECIFICATIONS

OF VESSELS DESCRIBED IN THE PLATES.

THOSE gentlemen who have kindly supplied the drawings from which the new plates are engraved, have given me also permission to make extracts from the specifications;—this is necessary to enable the reader to obtain information relative to the correct scantling of each vessel, the scale of the drawings being much too small for the purpose.

As this work is confined to the *construction* of iron ships, and not to their outfit or their lines (except so far as the latter have direct reference to the system of construction), I have omitted these subjects from the specifications, with all clauses so necessary in contracts relating to the quality of the workmanship and materials; it may be assumed that these are to be the best of the kind generally employed, and that all details usual in well-built ships would be applied.

There are also various peculiarities of construction employed in different countries and localities, but which do not materially affect the character of the ship; these, if enumerated, would unnecessarily extend the work, and would not advance the main subject.

It is satisfactory to observe that our leading men, whether naval architects or builders, feel less hesitation in laying open their plans to the public than formerly. There are now but few trade secrets; the qualifications which best enable builders to compete with each other are to be *found* in the relative efficiency of their

machines, the convenience of their yards, the experience of their managers, and their own determination to do good work.

The examples chosen to illustrate the character of iron ships built or building for the navy are seen in Plates XXXI. to XXXIV. Plate XXXI. is the midship section of the "Warrior;" XXXII., midship section of the "Hercules;" XXXIII., the details of the stem and stern of the "Bellerophon;" and XXXIV., the midship section of the "Seraphis"—one of the iron transports lately built as troop-ships for the Government.

The constructive details of the "Hercules," "Bellerophon," and "Monarch" are of the same character, but the thickness of the armour-plating differs. It will be observed that the "Hercules" has an inner thickness of timber below the main deck, which the others have not; the bow and stern also are generally the same, though differing in some particulars.

Specification of a Paddle Steam-Vessel, of Steel, drawing 12 *in. of Water, by Messrs. Money Wigram & Sons, of London.* (Plate XXV.)

Dimensions.—Length between perpendiculars, 150 ft.; breadth of beam, 20 ft.; height at vessel's side, 3 ft.; draught of water, 1 ft.

Plates, of steel; the floor or bottom, up to the 12 in. water-line, to be $\frac{1}{8}$ in. thick; the sides above the 12 in. water-line to be $\frac{3}{32}$ in. The plates to be 2 ft. wide, and from 10 to 12 ft. in length.

Rivets for the $\frac{1}{8}$ in. plates to be $\frac{7}{16}$ in., and for the $\frac{3}{32}$ in. plates to be $\frac{3}{8}$ in.

Frames, of angle iron, $1\frac{3}{4} \times 1\frac{1}{2}$ in., or $2\frac{1}{2}$ lbs. to the foot, 18 *in. apart.*

Keelsons to be plates $9 \times \frac{3}{16}$ in., strengthened by angle-bars

$1\frac{1}{2} \times 1\frac{3}{4}$ in.; also cross flooring $9 \times \frac{3}{16}$ in. thick, placed at every fourth rib. Gunwale to be angle-iron, $1\frac{1}{2} \times 1\frac{3}{4}$ in., fitted on the outside of the vessel.

Bulkheads, one fore, one aft, of engine-room, and one at the extreme ends of passengers' compartments, to be $\frac{3}{32}$ in. thick, with angle-iron, $2\frac{1}{2}$ lbs. to the foot, every 2 ft. 3 in. apart.

Engine Room 12 ft. wide; the sides to be longitudinal bulkheads of $\frac{3}{32}$ in. plate, with angle-iron $1\frac{3}{4} \times 1\frac{1}{2}$ in., placed 18 in. apart. The trussed girder, shown in drawing, to consist of an angle-iron $1\frac{3}{4} \times 1\frac{1}{2}$ in., riveted along the longitudinal bulkhead. The sides of compartments for passengers to be constructed in the same manner, but only as high as the main deck.

Main Deck Beams to be of angle-iron, $2\frac{1}{2}$ lbs. to the foot, to be forged at each end to an angle.

Engine Beams of iron, $6 \times \frac{1}{4}$ in., with an angle-iron $1\frac{3}{4} \times 1\frac{1}{2}$ in. riveted to the upper edge.

Paddle-Boxes to be supported by iron-plate beams $6 \times \frac{1}{4}$ in. Spring beams also of iron; the covering to be $\frac{1}{32}$ in. thick, with angle-iron $1\frac{1}{4}$ lbs. to the foot; sides to be $\frac{1}{16}$ in. thick, stiffened by angle-bars.

Specification of a Paddle Steam-Vessel, of Steel, by Messrs. Money Wigram & Sons. (Plate XXVI.)

Dimensions.—Length over all, 185 ft.; breadth, extreme, 25 ft.; depth in hold, 5 ft. 2 in.; draught of water, light, 2 ft. 3 in.

Keel.—Plates, $12 \times \frac{5}{16}$ in.

Frames, $2 \times 2 \times \frac{1}{4}$ in., 18 in. apart in midships, 2 ft. fore-and-aft.

Floor Plates, 8 in. deep, $\frac{1}{4}$ thick.

Keelson.—A plate $6 \times \frac{3}{8}$ in., strengthened with four angle-bars, $2 \times 2 \times \frac{1}{4}$ in.

Plating under engines and sides, up to paddle-shaft, $\frac{1}{4}$ in.; remainder $\frac{3}{16}$ in.

Deck Beams of T iron, $3 \times 4 \times \frac{3}{8}$ in., with plate-knees.

Deck Stringer, 18 in. wide, by $\frac{1}{4}$ in. thick.

Bulkheads.—To have two fore-and-aft and four athwartship bulkheads, $\frac{1}{8}$ in. thick, strengthened with angle-bars, $2 \times 2 \times \frac{1}{4}$ in.

Specification of the Steel Paddle Steam-Vessel "Scarbrough," from designs by Mr. John Grantham. (Plate XXVII.)

Length of hull between perpendiculars, 150 ft.; breadth of

hull between perpendiculars, 18 ft.; depth from base line to underside of gunwale, 8 ft.; draught of water, light, 3 ft. 3 in.

Stem Post.—An iron bar, 5 × 1 in.

Stern Post, of a bar, 4 × 2½ in.

Frames.—Every 18 in. in the engine compartment, and every 20 in. fore-and-aft, 3 × 2 × ¼ in. for 80 feet amidships, and 3 × 2 × $\frac{3}{16}$ fore-and-aft; about 10 frames under the engines are double at the bottom. Floors are stiffened by plates 12 × ¼ in., and by reverse bars 2½ × 2 × $\frac{3}{16}$ in., running to the top side of bilges, and up every alternate frame.

Keelsons.—Centre keelson, a plate 6 × ⅜ in., with four angle-bars 2 × 2 × ¼ in. Two sister keelsons, each about 80 ft. long, and consisting of two angle-bars 3 × 3 × ¼ in.

Plates.—Centre plate of bottom 24 × ⅜ in., dished 1 in. in the centre to form a limber for the water; bottom plates for 60 ft. amidships, and to the 2 ft. water-line, ¼ in., and remainder fore-and-aft, and the side plates, $\frac{3}{16}$ in., except the sheer-strake, which is ⅜ in. for 60 ft. amidships, ¼ in. at the ends.

Rivets.—Lowmoor iron, ⅝ and ½ in. in diameter.

Engine and *Boiler Beds* to be of steel.

Bulkheads, four in number, connected to the sides by two angle-bars 2 × 2 × $\frac{3}{16}$ in., and stiffened by the same every 2 ft.; bottom for 2 ft. up to be ¼ in. plates, and the remainder $\frac{3}{16}$ in. thick.

Stringers, in the upper deck, of an angle-bar 3 × 3 × ¼ in., and a plate 2½ ft. wide, and a ¼ in. in the engine compartment, gradually diminishing to 15 × $\frac{3}{16}$ in. at the ends; lower stringer and angle-bars 3 × 3 × ¼ in. riveted together, and a plate 12 × ¼ in. in the engine-room secured to short reverse angle-bars on the frames. The sides under paddle-shaft to have extra fastenings.

Deck Beams.—Angle-bars 5 × 2½ × ¼ in., and 3 × 2½ × $\frac{3}{16}$ in., having gusset pieces at the gunwale, 12 in. deep × $\frac{3}{16}$ in. thick, attached to alternate frames.

Stanchions, three in number in after cabin, and five forward, to be of bars 1½ in. in diameter, with a bar of T iron, 4 × 4 × ⅜ in., running horizontally under the beams down the centre of the cabins.

Paddle Beams of plates 15 × ⅜ in., with four angle-bars 3 × 3 × ¼ in.; angle-plates run from these down to the bilges, 18 in. wide at the top, and 4 in. at the bottom, × ¼ in. thick; about five other beams on each side to support the wing pieces, ¼ in. thick, and angle bars 3 × 3 × $\frac{3}{16}$ in. on each side;

three of these have diagonal stays with a broad foot riveted to ship's sides, of bar iron $1\frac{1}{4}$ in. diameter, also diagonal paddle beam-stays $1\frac{3}{4}$ in. diameter, all of steel.

Rudder Stock of iron, $3\frac{1}{2}$ in. diameter, and rudder 6 feet long. The plates are of iron, each $\frac{3}{16}$ in. thick; casing of rudder from transom to deck to be water-tight.

Rudder forward, about ten superficial feet, is placed in the forefoot, and protected by the stem post, as shown in the drawing.

Crutches to be applied fore-and-aft as may appear necessary, and be of plates $\frac{3}{16}$ in. thick.

Deck Plank to be of best yellow pine, 3 in. thick $\times$ 6 in. wide.

Cabin Sole, $1\frac{1}{2}$ in. plank, 6 in. wide.

Covering Board to be of red pine, 14 in. wide and 5 in. thick, bolted to stringer plates by $\frac{5}{8}$ in. bolts and nuts every 9 in., and project over the side so as to form a moulding.

Bulwarks to be 3 ft. 1 in. high aft, and 3 ft. 3 in. forward. Stancheons are of English oak, 4 in. square.

Coamings to be cased with oak in the way of companions; hatches to be of oak 10 $\times$ 3 in.; those over the boiler to be 12 $\times$ 3 in.; engine-room and boiler hatches raised $2\frac{1}{2}$ ft. $\times$ 2 in.

Spring Beams.—The upper piece to be Quebec elm, 6 $\times$ 16 in., the lower piece to be of red pine, 3 $\times$ 12 in.

Paddle-Boxes to be of $1\frac{1}{4}$ in. red pine, rebated and framed with Quebec elm. The deck of the vessel to be sponsoned out 18 in. on each side forward of the paddle-box.

Specification of a Steel Paddle-Wheel Steamer for the Channel Service, proposed by Mr. J. Grantham. (Plates XXVIII, XXIX.)

Length, 450 ft.; beam, 54 ft.; depth below cabin, 8 ft.; height of cabin, 10 ft., and height under platform, 10 ft; height of sides from base line for 140 ft. amidships to be 27 ft., tapered off to the height of bulwarks fore-and-aft. There will be three longitudinal bulkheads from the engine compartment fore-and-aft; these will come up to the lower or iron deck. In the engine compartment there will be two longitudinal bulkheads extending to the main deck. Both ends to be similarly formed, and to be so constructed as to admit of rudders for steering each way; these will be enclosed in a strong frame of wrought iron.

Side Frames to be spaced every 2 ft., to be angle-bars 4 × $2\frac{1}{2}$ × $\frac{1}{4}$ in., with reverse bars 2 × 2 × $\frac{3}{16}$ in. In the engine compartment the alternate side frames will be stiffened by three plates 24 in. wide, × $\frac{1}{4}$ in. Floors to be the same as the side frames, and to be continued to the top of the raised sides and of the paddle-boxes.

Stringers of main deck to be 13 ft. × $\frac{1}{4}$ in., stiffened longitudinally by two intercostal frames, those in engine compartment being a plate 15 in. deep, and those fore-and-aft to be angle bars 6 × 2 in.; stringers for the platform deck amidships 3 ft. × $\frac{1}{4}$ in., all chain riveted. Deck under the cabin to be all plated water-tight, to be $\frac{5}{32}$ in. thick; two longitudinal stringers on the sides, each of two angle-bars 4 × $2\frac{1}{2}$ × $\frac{1}{4}$ in.; also two stringers on the paddle-boxes to be angle-bars 3 × 2 × $\frac{1}{4}$ in.

Beams to be attached to the alternate frames for platform deck to be bulb-iron, from 5 × 2 × $\frac{1}{4}$ in., and the same for the main deck; for the lower iron deck to be angle-bars 3 × 2 × $\frac{1}{4}$ in., supported 7 ft. from the centre by iron stancheons 1 in. diameter. Gusset plates of steel, to be 18 × $\frac{1}{4}$ in.

Plates for the outer shell to vary from $\frac{3}{8}$ in. amidships to $\frac{1}{4}$ in. For the longitudinal bulkheads, $\frac{3}{16}$ and $\frac{5}{32}$ in.; midship transverse bulkheads to be $\frac{1}{4}$ and $\frac{3}{16}$ in., stiffened by angle-bars 3 × 2 × $\frac{3}{16}$ in., 2 ft. asunder, corresponding with the frames.

Keelsons.—The centre and two side keelsons fore-and-aft the engine compartment will be formed by the three longitudinal bulkheads as above described. Each of the four compartments will also have a keelson of two angle-bars, 4 × 2 × $\frac{1}{4}$ in. The engine beds will be made to suit the engines and boilers.

Truss Beams, as shown in the drawings, to be formed of $\frac{1}{4}$ in. plate and angle-bars 3 × 3 × $\frac{3}{16}$ in. Stancheons under these to be of tubes 4 × $\frac{3}{16}$ in.; other stancheons in cabins and under platform to be tubes 3 × $\frac{3}{16}$ in.

Bulwarks at the ends to be $4\frac{1}{2}$ ft. high, to be of steel $\frac{4}{16}$ in. thick, stiffened by angle-ribs every 3 ft., 3 × 2 × $\frac{3}{16}$ in. Rail to be two angle-bars 3 × 3 × $\frac{1}{4}$ in.

WOODWORK.

Main Deck, pine, 6 × 3 in.; lower deck to be $1\frac{1}{2}$ in. plank laid on battens placed athwartships, to be 6 × 1 in. every 2 ft.; platform deck to be 6 × 2 in., tongued and grooved.

Cabins, under side of deck, to be panelled with $\frac{1}{2}$ in. pine, and sides to be lined with $\frac{3}{4}$ in. pine.

Paddle-Boxes to have an outer rim of oak, to be framed with

double king posts well braced with iron; the outsides and tops to be pine $1\frac{1}{2}$ in. thick, tongued and grooved, to have three internal rings of angle-bars $4 \times 2 \times \frac{1}{4}$ in.

"Persian" Iron Screw Steamer, built by Messrs. Harland and Wolff, of Belfast. (Plate XXX.)

Dimensions.—Length between perpendiculars, 361 ft. 8 in.; beam, 34 ft.; depth of hold, 25 ft.

Keel of forged iron, $9 \times 3\frac{1}{2}$ in.; stern post, 13×6 in.; stem, 9×3 in.

Main Keelson.—Vertical plate 24 in. deep at the centre, tapered to 9 in. at ends, $\times \frac{3}{4}$ in. thick; also four bars of angle-iron $5 \times 5 \times \frac{5}{8}$ in., and flat plate on the top $12 \times \frac{5}{8}$ in.

Sister Keelson formed of an intercostal plate, having on the top one bar of bulb-iron $8 \times \frac{3}{4}$ in., and two bars of angle-iron $5 \times 5 \times \frac{5}{8}$ in.

Bilge Keelsons.—Two on each side, formed of bulb and angle-iron as above, and one of two bars of angle-iron only.

Beams on main and lower decks, 3 ft. apart, to be of bulb-iron $6 \times 4 \times \frac{7}{8}$ and $\frac{5}{8}$ in. Orlop beams, as shown in the drawing, each of two bars of bulb-iron placed back to back.

Frames of angle-iron $5 \times 3\frac{1}{2} \times \frac{5}{8}$ in., spaced 18 in. apart.

Reverse Frames $3\frac{1}{2} \times 3 \times \frac{1}{2}$ in., carried alternately to main and lower decks.

Floors of plate-iron 2 ft. deep amidships $\times \frac{5}{8}$ in.

Stringer in Lower Hold, angle-iron, $5 \times 5 \times \frac{5}{8}$ in.; orlop deck, bulb-iron, $8 \times \frac{3}{4}$ in., and angle-iron $5 \times 5 \times \frac{5}{8}$ in.

Lower Deck Plate 36 in. wide, tapered to 24 in. at the ends, by $\frac{3}{4}$ in. thick; main-deck plate, $26 + \frac{3}{4}$ in.; lower-deck tie plates, $12\frac{1}{2} \times \frac{3}{4}$ in.

Plates.—Keelstrake, 1 in.; flat of floor to the turn of bilge, $\frac{15}{16}$ in.; turn of bilge to the flat of side, $\frac{14}{16}$ in.; flat of sides, $\frac{13}{16}$ in.; sheerstrake, $\frac{14}{16}$ in.; bulwarks, $\frac{5}{16}$ in. All plates reduced towards the ends from $\frac{1}{10}$ to $\frac{1}{8}$ in. in thickness. Bilge and sheerstrakes, with two others on the sides, doubled amidships.

Main Deck of iron, made with Harland's chequered plates, 20 lbs. per square foot amidships, reduced to 15 lbs. at the ends.

Main Rail of Bulwarks, a solid bar $8 \times \frac{5}{8}$ in.

Specification of the Iron Screw Steam Frigate "Warrior." (Plate XXXI.)

Principal Dimensions.—Length between perpendiculars, 380 ft.; breadth, extreme, to outside of plates, 58 ft.; depth in hold,

from top of floors to upper side of orlop deck beams, 21 ft. 1 in.; burthen in tons, O. M., 6,038 $\frac{84}{94}$.

Keel.—The vertical plate to be 40 in. deep by $\frac{3}{4}$ in., and to extend from the stern-post to the stem, and to be riveted to them. The flat keel plates to be in two thicknesses; four bars of angle-iron, two of which will connect the vertical with the flat keel plates, to be $6 \times 6 \times 1$ in., rivets $1\frac{3}{8}$ in. Angle-iron, on the upper edge of the vertical plates, to be $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in., worked in short lengths.

Flat Keelson Plate to be 3 ft. $\times \frac{3}{4}$ in., to be treble riveted, and to have double butt-straps.

Stern Frame.—The rudder-post to be 10×20 in., the body post 10×18 in. Boss for screw to be made to the engineer's drawings.

Longitudinal Frames, for 280 to 320 ft., to be of plates and angle-irons as follows:—

	Plate.	Angle Irons.	
		Inner Edge.	Outer Edge.
The upper longitudinal frame, as also the plates forming the fore and after ends of the recess for the armour-plates, to be made of a flanged plate; or forged, fitted, and planed, as may be directed . .	$23 \times \frac{7}{8}$	$5 \times 5 \times \frac{5}{8}$	$6 \times 6 \times \frac{3}{4}$ if required.
			To be doubled.
2nd longitudinal frame .	$21 \times \frac{1}{2}$	$3\frac{1}{2} \times 3 \times \frac{9}{16}$	$4 \times 3\frac{1}{2} \times \frac{5}{8}$
3rd do. do. .	$27 \times \frac{5}{8}$	$3\frac{1}{2} \times 3 \times \frac{9}{16}$	$4 \times 3\frac{1}{2} \times \frac{5}{8}$
4th do. do. .	$19 \times \frac{1}{2}$	$3\frac{1}{2} \times 3 \times \frac{9}{16}$	$4 \times 3\frac{1}{2} \times \frac{5}{8}$
5th do. do. .	$19 \times \frac{1}{2}$	$3\frac{1}{2} \times 3 \times \frac{9}{16}$	$4 \times 3\frac{1}{2} \times \frac{5}{8}$
6th do. do. .	$27 \times \frac{5}{8}$	$4 \times 3\frac{1}{2} \times \frac{9}{16}$	$4 \times 3\frac{1}{2} \times \frac{5}{8}$

Floor Plate, on each side of vertical keel plate, to be $\frac{5}{8}$ in. thick, and secured to it by the frame angle-irons.

All transverse plates to be $\frac{1}{2}$ in. thick; bulkheads to be $\frac{5}{8}$ in. thick.

Frame Angle-Irons, on the outer edge of the floor plates, are to be $4 \times 3\frac{1}{2} \times \frac{5}{8}$ in.; those on the other transverse plates to be $4 \times 3\frac{1}{2} \times \frac{9}{16}$ in.; all to be double bars, except where specified to be single.

Intermediate Floor Plates, &c., $\frac{1}{2}$ in. thick, are to extend from

the keel to the lowest longitudinal frame; to have an angle-iron $7 \times 3\frac{1}{2} \times \frac{5}{8}$ in. on one side of thin upper edge, and an angle-iron $4 \times 3\frac{1}{2} \times \frac{5}{8}$ in. on one side of thin lower edge; the upper bars to extend across the keel. Frames between the longitudinals to be spaced every 3 ft. 8 in.; fore and aft of this to be spaced every 22 inches. In wake of the armour plates these frames to be $10 \times \frac{1}{2}$ in. and angle-irons. The angle-iron on the inner edge $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in.; on the outer edge to be double $3\frac{1}{2} \times 4\frac{1}{2} \times \frac{5}{8}$ in.

Reverse Frames.—A reverse angle-iron to be fitted to every frame throughout the ship.

Intermediate Frames.—A short intermediate frame is to be worked between each of the regular frames behind the armour plates, and to have angle-irons of the same scantlings as the main frames, but the plates to be $\frac{7}{16}$ in. thick, to extend from the upper deck to the third longitudinal frame; plates similar in all respects to those of the frames are to be worked between the two upper longitudinal frames, to receive thin heels, which are to be seamed as the overseer may direct. The heads of these frames are to be firmly secured to the under side of the stringer plate on upper deck by angle-irons.

Transverse Frames before and abaft Armour Plates.—For 30 feet next before and abaft the armour plates the continuous frames are to be formed of angle-irons $7 \times 4 \times \frac{5}{8}$ in.; the reverse frames to be $3\frac{1}{2} \times 3 \times \frac{9}{16}$ in., with plates attached where directed. Before and abaft the armour plates the frames are to be $6 \times 4 \times \frac{9}{16}$ in., the reverse frames $3\frac{1}{2} \times 3 \times \frac{9}{16}$ in.; and beyond this the frames are to be $5 \times 4 \times \frac{9}{16}$ in., and the reverse frames $3\frac{1}{2} \times 3 \times \frac{1}{2}$ in. A floor plate with a reverse angle-iron to each frame.

Vertical Girders to Armour Plate Bulkheads to be plates $10 \times \frac{1}{2}$ in., with double angle-irons $4\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in. on the edge next the wood backing, and one reverse angle-iron $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ in.

Internal Plating.—Plates $\frac{5}{8}$ in. thick are to be worked on the throat of floors between the lower longitudinal frames on each side, extending as far forward and aft as may be required: they are to be attached to the floors and longitudinal frames so as to form water-tight compartments.

Outside plates to be as follows:—

	For a length of about 250 feet Amidships.	Forward and Aft.
	Ins.	Ins.
Middle line or keel strakes { Upper . . .	$1\frac{1}{8}$	$1\frac{1}{8}$
Middle line or keel strakes { Lower . . .	$1\frac{1}{4}$	$1\frac{1}{4}$
Next two strakes out on each side . . .	$1\frac{1}{8}$	$\frac{7}{8}$
Next strake	1	$\frac{7}{8}$
Thence to 14 feet water line	$\frac{7}{16}$	$\frac{13}{16}$
From 14 feet water line, except behind armour-plates	$\frac{13}{16}$	$\frac{12}{16}$
Plating behind armour-plates in about 12 feet beyond each end of the recess . . } Lower strake	$\frac{5}{8}$	
Plating behind armour-plates in about 12 feet beyond each end of the recess . . } Remainder .	$\frac{9}{16}$ Strake under ports double, or two of $\frac{9}{16}$.	
Between the ports, forward and aft . . .	—	$\frac{9}{16}$
Sheer strake to be worked in two thicknesses, each	$\frac{5}{8}$	$\frac{9}{16}$

Deck Beams to be as follows:—Upper deck beams, $12 \times \frac{1}{2}$ in.; main deck beams, $16 \times \frac{7}{16}$ in.; lower deck beams, $15 \times \frac{6}{16}$ in. Half beams to be fitted to all the decks as shown on the plans, and of the form and dimensions as directed. Platform beams to be of the depth shown on the profile, or as directed, and to be either the solid beams, as above, or made up by a bulb-iron with angle-irons on the top edge as directed. The flanges to be covered by mouldings where required.

Plating on Deck Beams.—The upper deck to be of $\frac{1}{4}$ in. plates. A tie and diagonal plates 24 in. broad, and a stringer plate 3 ft. 6 in. broad round the side, to be $\frac{5}{8}$ in. thick, worked on the top of the $\frac{1}{4}$ inch plates. The side stringer to be attached to the sheerstrake by angle-irons $6 \times 4 \times \frac{3}{4}$ in. for 20 feet before and abaft the armour plates, the remainder to be $5 \times 3\frac{1}{2} \times \frac{5}{8}$ in., and short angle-irons $4 \times 4 \times \frac{9}{16}$ in. between the frame under the stringer, as on main deck. The entire surface of the main deck to be plates $\frac{1}{4}$ in. thick, tie plates 20 in., and stringer plates 4 ft. 6 in. broad, excepting at the termination of the recess, where it is to be $\frac{5}{8}$ in. thick. The deck plating to be scored home to the side of the ship by short angle-irons above and below, $4 \times 4 \times \frac{9}{16}$ in., and to the reverse irons of the frames by an angle-iron on the upper side, $4 \times 4 \times \frac{9}{16}$ in.

Lower Deck to have a stringer plate round the side to the *breadth of* the wing passage, angle-irons to be the same as the *main deck;* also tie plates at the side of hatchways. Plates

$\frac{5}{8}$ in. thick attached to the deck beams in the wake of the mast holes.

Pillars in Hold and between Decks to be wrought-iron tubes as follows:—Pillars in hold, 7 in. diameter, $\frac{1}{2}$ in. thick; pillars on lower deck, 5 in. diameter, $\frac{3}{8}$ in. thick; pillars on main deck, $4\frac{1}{2}$ in. diameter, $\frac{5}{16}$ in. thick. Solid pillars, and to be fitted wherever required in the engine and boiler rooms.

Water-tight Bulkheads to be supported by angle-irons $4\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in., placed vertically 30 in. apart; to be double where required, so as to enclose a water-tight space between them; the thickness of the plates to be as follows:—After bulkhead, to receive stuffing-box plates below lower deck, $\frac{7}{8}$ in.; above lower deck, $\frac{5}{8}$ in. Two foremost bulkheads to be $\frac{5}{8}$ in. throughout. Bulkheads receiving thick armour plates to be $\frac{5}{8}$ in. thick to lower deck, and above lower deck $\frac{1}{2}$ in. thick. Remainder all $\frac{5}{8}$ in. to about 14 ft. water line; thence to lower deck, $\frac{9}{16}$ in.; above lower deck, $\frac{7}{16}$ in.

Wing Passage Bulkheads, on each side, as shown on the plans, and extending up to main-deck plating, to which it is to be secured by angle-irons, and to be made water-tight; the plating of the bulkheads to be $\frac{5}{8}$ in. at lower part, $\frac{9}{16}$ in. at lower deck, and $\frac{7}{16}$ in. between decks; to be supported by angle-irons placed vertically 1 ft. 10 in. apart. To have transverse divisional bulkheads of the same thickness as the wing-passage bulkheads.

Shaft Passage.—Plates $\frac{1}{2}$ in. thick, and angle-irons $3 \times 2\frac{1}{2} \times \frac{3}{8}$ in., placed 18 in. apart.

Internal Longitudinal Stringers to be plates $\frac{3}{8}$ in., and angle-irons, $3 \times 3 \times \frac{1}{2}$ in., are to be fitted between the ports on the main deck.

External Longitudinal Stringers to be plates $10 \times \frac{5}{8}$ in., with angle-irons $4\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in. on the inner edge.

Bilge Keels, two on each side, to be formed of plates $\frac{7}{8}$ in. thick and 15 in. deep, with half-round irons on the edge secured by two angle-irons $5 \times 4\frac{1}{2} \times \frac{5}{8}$ in. The upper bilge keel to be about 97 ft. long, the lower one 153 ft. long.

Iron Port Sills to be plates $\frac{1}{2}$ in. thick.

Breast Hooks to be fitted as shown on the profile and plans.

Bulkheads enclosing the Well for the Screw.—Plates $\frac{5}{8}$ in. thick.

Engine Boiler and Shaft-Bearers to be fitted as directed, and continued forward and aft as required for keelsons, $\frac{3}{4}$ in. plates to be worked on the frames under the engine-bearers whenever required by engineer.

Stern Frame Quarter Galleries, &c., to be of $\frac{1}{2}$ in. plates and angle-irons 5 × 4 × $\frac{5}{8}$ in., with a reverse angle-iron $3\frac{1}{2}$ × 3 × $\frac{1}{2}$ in.

Topside Timbers to be of teak sided 10 in., moulded as shown on the section, and spaced as will be directed; gunwale to be 6 in. thick and 25 in. broad, of oak or teak; planksheer and topside planking to be teak or mahogany.

Arrangements for Fitting Armour Plates, Wood Backing, &c., to be composed of two thicknesses of East India teak, worked on a teak shelf; the inner thickness, 10 in., placed longitudinally, the outer to be 8 in., worked vertically. The edges and butts of the armour plates are planed and well fitted, and to be formed so as to bill into each other.

Waterways on the several decks to be of teak. Upper deck, 12 × 12 in.; main deck, 11 × 11 in.; lower deck, 11 × 6 in.

Planking Upper Deck, 4 in. Dantzic deals; main deck, Dantzic oak, $4\frac{1}{2}$ in. thick; lower deck, Dantzic deals, 4 in. thick.

Specification of H.M. Steam Frigate "Hercules," designed by Mr. E. J. Reed, Chief Constructor of the Navy. (Plate XXXII.)

Dimensions.—Length between the perpendiculars, 300 ft.; breadth, extreme, to outsides of plates, 56 ft.; depth in hold, from top of inner plating to upper side of lower deck beams, 17 ft. 3 in.; burthen in tons, O. M., 4,246 $\frac{8}{9}\frac{9}{4}$ tons.

Keel.—Vertical keel plates to be $\frac{3}{4}$ in. thick, and 53 in. deep, in the length of the double bottom; the remainder to be tapered as required. The flat keel plates to be in two thicknesses, as shown in the midship section. The angle-irons connecting them to be 6×6×1 in. and $1\frac{3}{8}$ in. rivets. The keel plates to be attached to the stern post with angle-irons; butt straps to be treble chain riveted, and their breadth to be sixteen times the diameter of the rivets. The butt straps of the keel angle-irons to be 1 in. thick. The rivet holes are either to be drilled or rimed out after being punched; rivets to be $1\frac{1}{4}$ in. diameter. The keel to be caulked, so that it may divide the double bottom into two water-tight compartments. Angle-iron on top of vertical keel plate to be $3\frac{1}{2}$×$3\frac{1}{2}$×$\frac{9}{16}$ in., worked in short lengths.

Rudder and Body Posts.—The rudder post, with eyes, &c., complete, is to be forged in one piece, to be 10 in. athwartships by 20 in. fore-and-aft; the body post, 22 in. athwartships and 21 in. fore-and-aft, also to be in one piece. The top of the

rudder post is to be formed with two arms to support it on each side, running up transversely on the inside of the skin to the main deck. A $4\frac{1}{2}$ in. plate is to be welded horizontally on the top of the body post, to connect it with the frame of the ship.

Tube for Screw Shaft, for 10 ft. of its length, is to be formed mostly of 1-inch plates. The remainder to be 2 in. thick; to be securely fastened to the post and to the stuffing-box bulkhead, and to be built into the frame of the ship.

Stem to be forged in three lengths; the lower end is to be scarfed on the vertical keel plate.

Longitudinal Frames to be formed of plates and angle-irons of the following dimensions:—Recess for armour to be of plates $16\times\frac{7}{8}$ in., and double angle-iron $5\times5\times\frac{5}{8}$ in. No. 1, or upper longitudinal frame, to be $17\times\frac{7}{16}$ in.; inner edge of angle-iron, $3\times3\times\frac{1}{2}$ in.; outer edge, $4\times3\frac{1}{2}\times\frac{9}{16}$ in. No. 2 longitudinal frame to be $31\times\frac{1}{2}$ in. No. 3 frame to be $38\times\frac{7}{16}$ in. No. 4 frame to be $42\times\frac{7}{16}$ in. No. 5 frame to be $49\times\frac{1}{2}$ in. The plate and angle-irons to be continuous from stem to stern. No. 1 longitudinal is to be the same breadth, viz., 17 in. throughout its entire length. Nos. 2, 3, and 4 longitudinals are to taper forward and aft as required, and are to be continuous from the stem to the stuffing-box bulkhead. No. 5 longitudinal, or the one nearest the keel, is to taper forward and aft, if required. The inner angle-irons on the longitudinals are to be worked in short lengths between the frames, in the double bottom, and are to be continuous before and abaft it. Nos. 1, 3, 4, and 5 longitudinals to have double butt-straps half the thickness of the plates, and double chain riveted. The outer angle-irons to be bent, and the longitudinals scored, so as to fit over the butt-straps to the bottom plates; but, to prevent a sudden angle, tapered liners are to be used on each side the straps. The plates of Nos. 3, 4, and 5 longitudinals are to be lightened by being pierced with holes between the frames in the double bottom. Holes to be 2 ft. long by 1 ft. No holes are to be taken out where the longitudinal plates butt.

Transverse Frames behind Armour to be 2 ft. apart, of angle-iron $10\times3\frac{1}{2}\times\frac{1}{2}$ in., with two angle-irons on the outside $3\frac{1}{2}\times3\frac{1}{2}\times\frac{5}{8}$ in., to be carried down from the bottom of the armour to the 2nd longitudinal situated at the foot of the wing-passage bulkhead, where the $10\times3\frac{1}{2}\times\frac{1}{2}$ in. angle-irons are to be reduced to $5\frac{1}{2}\times3\frac{1}{2}\times\frac{1}{2}$ in. Before and abaft the double bottom the frames to be $4\times3\frac{1}{2}\times\frac{1}{2}$ in. Of these frames, every other one is to be continued from the 2nd longitudinal across the

keel to the opposite side by angle-iron $5\frac{1}{2} \times 3\frac{1}{2} \times \frac{7}{16}$ in. in the double bottom, and $4 \times 3\frac{1}{2} \times \frac{7}{16}$ in. before and abaft. Between the armour recess and the 2nd longitudinal, each frame behind the armour is to be completed by plates $\frac{7}{16}$ in. thick. The angle-irons on the outer part of these frames between the recess and the 1st longitudinal to be $4 \times 3\frac{1}{2} \times \frac{9}{16}$ in. from stem to stern. The angle-irons on the outer part of the frames between the 1st and 2nd longitudinals to be $5\frac{1}{2} \times 4 \times \frac{9}{16}$ in., except those before and abaft the double bottom, which are to be $4 \times 3\frac{1}{2} \times \frac{9}{16}$ in. The short angle-irons connecting the frame plates to the longitudinals to be $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{7}{16}$ in.

Transverse Frames in Double Bottom to be 4 ft. apart, and composed (excepting those under the engine bearers, and those before and abaft No. 5 longitudinal, as shown in the midship section) of the continuous angle-irons before described; of the outside angle-irons $5\frac{1}{2} \times 4 \times \frac{9}{16}$ in., worked in short lengths between the longitudinals; of short angle-irons $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{7}{16}$ in., connecting to the longitudinals; and of bracket plates $\frac{7}{16}$ in. thick, uniting all these angle-irons.

Transverse Frames, before and abaft the double bottom, and below the 2nd longitudinal, to be 4 ft. apart, and to be composed of $\frac{7}{16}$ in. plates of the $4 \times 3\frac{1}{2} \times \frac{7}{16}$ in. continuous angle-irons, of $4 \times 3\frac{1}{2} \times \frac{7}{16}$ in. outside single angle-irons in short lengths between the longitudinals, and of short angle-irons $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{7}{16}$ in., connecting them with the longitudinals.

Water-tight Frames.—At intervals of about 20 ft. the double bottom to have water-tight frames formed of plates $\frac{1}{2}$ in. thick, and angle-iron $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ in.

Transverse Frames above the armour belt, before and abaft the battery, are to be 4 ft. apart, to run up to the planksheer, and to be composed of angle-irons $7 \times 3\frac{1}{2} \times \frac{7}{16}$ in.; to be continuations of every other one of the frames behind armour, being riveted to the deep flanges of the $10 \times 3\frac{1}{2} \times \frac{1}{2}$ in. angle-irons, which are continued up through the deck-plating; between these frames are to be $4 \times 3\frac{1}{2} \times \frac{9}{16}$ in. angle-irons, connected to the deck-plating with a foot, and forming intermediate angle-irons for the support of the topside plating.

Reverse Frames to be fitted where required.

Inner Bottom to be water-tight, and of $\frac{1}{2}$-inch plate made flush with butts on the under side. The vertical plate under the main-deck stringer to be $\frac{7}{16}$ in. thick between the main and lower decks, forming the wing-passage bulkhead, and

$\frac{1}{2}$ in. thick below, to be lap-jointed, to have stiffeners of angle-irons $4 \times 3\frac{1}{2} \times \frac{5}{8}$ in., one between every two beams having a turned foot about 12 in. long. Edges to be single riveted, and butts treble chain riveted. A manhole, with a water-tight cover, to be fitted in the plating on floors.

Transverse Bulkheads (*water-tight*).—The plates to be $\frac{1}{2}$ in. thick below the lower deck, and $\frac{7}{16}$ in. above it, supported by angle-irons $3\frac{1}{2} \times 3 \times \frac{9}{16}$ in. every 30 in. Three of the bulkheads are to be $\frac{5}{8}$ in. thick, flush-jointed; two others to be supported on one side by angle-irons $3 \times 3\frac{1}{2} \times \frac{9}{16}$ in. every 4 ft., and on the other side by T-irons $4\frac{1}{2} \times 2\frac{2}{3} \times \frac{1}{2}$ in., to cover the joints. The plating of the bulkhead in make of tube to be $\frac{3}{4}$ in. The bulkheads to be water-tight, and where attached to the inner bottom to have double angle-irons $3\frac{1}{2} \times 3 \times \frac{9}{16}$ in.

Water-tight Doors, Sluice Valves, Manholes, &c., are be fitted in the bulkheads.

Water-tight Trunks to be built, for affording access to the spaces between the bottoms and between decks, as may be directed.

Outside Plating above the armour to be flush, and the fore part of the bottom plating doubled. The thickness of plates to be as follows:—Middle line or keel strake, upper, 1 in.; middle line or keel strake, lower, $1\frac{1}{8}$ in.; next strake, on each side, 1 in.; next two strakes, for 180 ft. amidships, $\frac{7}{8}$ in.; fore-and-aft, $\frac{15}{16}$ in.; remainder, up to the recess for armour, $\frac{13}{16}$ and $\frac{3}{4}$ in.; the plate attaching to armour, $\frac{7}{8}$ and $\frac{13}{16}$ in.; plating behind armour plates, two thicknesses, each $\frac{3}{4}$ in., reduced gradually to two thicknesses of $\frac{1}{2}$ in. each; plate next above armour, $\frac{5}{8}$ in.; remainder, above armour, $\frac{1}{2}$ in. The plates forming the after ends, and those next adjoining them, of all the strakes of bottom, except the keel strakes, are to be 1 in. The plating ending on the post is to be treble-tap riveted to it, and the plating ending on each side of the ship above the post is to be connected together, and secured by means of two thicknesses of plates. The inner one to be 1 in. thick and 31 in. wide, and the outer one $1\frac{1}{16}$ in. thick and about 43 in. wide.

Forecastle Beams to be 7 in. deep. *Upper Deck* to be 10 in. deep from stem to stern, and to be formed thus, T. *Main Deck* to be 14 in. deep from stem to stern, to be formed thus I in the battery amidships, and thus T before and abaft the battery, to the cant sections to be $\frac{1}{2}$ in. thick, with double angle-irons on both edges, each $3 \times 3 \times \frac{1}{2}$ in. *Lower Deck Beams* to be 14 in. deep, and all made of $\frac{1}{2}$ in. plates with double angle-irons;

those on the upper edge 3 × 3 × ½ in., and those on the lower 2½ × 2½ × ½ in. *Platform Beams* to be of bulb-iron, 8 in. deep, ½ in. thick, with angle-irons on the upper edge 3 × 3 × ⅜ in. In other necessary places stronger beams are to be introduced as required. *Half-beams* and *Carlings* in all decks to be the same depth and section as the beams.

Plating on Decks.—Upper deck, on the after part, from the sides to within 7 ft. of the middle line, to be ½ in. steel plates; remainder of deck to be ¼ in. plates. Butts to be treble chain riveted. Centre of deck to be covered with iron plates; all plates in length not less than 16 ft.

Main Deck to be ½ in. plates, flush jointed. Ties to be continued in breaks of the deck by the battery, by stringers 3 ft. 9 in. wide, running under the beams. Double plating in the wake of bitts, capstans, and masts.

Lower Deck to have a stringer plate ½ in. thick round the sides, to 4 in. more than the breadth of the wing passage. Plates ⅝ in. thick, attached to the deck beams, in the wake of the mast-holes, bitts, &c.

Plating on Platforms in Hold to be flush, and formed with plates ⅜ in. thick.

Pillars in Hold to be wrought-iron tubes, with heads and heels welded in solid.

The Diameters and Thicknesses.—Under guns in battery, from the hold to carlings under beams, 8 × ½ in.; remaining pillars in hold, 6 × ⅜ in.; pillars on lower deck, 5 × ¼ in.; pillars under guns and capstans, 6 × ⅜ in.; pillars under forecastle, 4 × $\frac{3}{16}$ in. Solid pillars are to be fitted as may be directed in the engine and boiler rooms.

Shaft Passage.—The shaft passage and passage connecting the engine and boiler rooms to be formed as may be directed, with plates ½ in. thick, and angle-irons 3 × 3½ × ½ in. placed 4 feet apart; all to be made water-tight.

Bilge Keels and False Keels to be fitted as shown in the midship section, two on each side, formed of wood, and secured to the bottom plates by angle irons, 5 × 4 × $\frac{9}{16}$ in. Tap riveted, if required. The upper bilge keel to be about 112 ft. long, and the lower one 144 ft. long.

Breast Hooks for the support of the stem and the termination of the water-tight flat forward are to be in accordance with the drawing.

Short Angle-Iron Frames above battery, and protected portions forward and aft, to be of 4 × 3½ × $\frac{9}{16}$ in., as shown in

the midship section, and spaced 2 ft. apart. These frames are to be strengthened where required.

Planksheer to be formed of an angle-iron $7\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ in., running from the forecastle to the stern, and connected to the side plating by an angle-iron $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ in., and to the frames as may be directed.

External Longitudinal Girders, formed of angle-iron, $10 \times 3\frac{1}{2} \times \frac{1}{2}$ in., behind the armour-plates, and attached to the skin-plating, as shown in the midship section; the deep flange of the angle-iron to be rather less in depth than the wood backing. Two girders to each strake of plates, each about 1 foot from the joints.

Wood Backing behind Armour to be 10 in. thick amidships, tapering in proportion to the thickness of the armour at the extremities of the ship; to be East Indian teak, $1\frac{1}{16}$ and 1 in. bolts.

Armour Bulkheads at the end of the battery are to be formed of plates $4\frac{1}{2}$ in. thick, placed vertically, backed by 10 in. frames of angle-irons, similarly to the frames of the sides behind the armour, with the $3\frac{1}{2}$ in. flanges next the armour; the skin, which is to be $\frac{3}{4}$ in., to be on the inside of all, and riveted to the $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ in. double angle-iron of the frame. The wood backing to be 10 in. deep, and worked between them, and also between the armour and skin. The fastening for wood backing and armour is to be similar to that for the side. Armour doors are to be fitted, two to each bulkhead, and 6 in. thick of iron. The ship is to be lined throughout between the upper and main decks with $1\frac{1}{2}$ in. teak or "Burnettised" wood, and wherever else directed. The frames above the upper deck to be lined with 2 in. teak or "Burnettised" wood.

Gutters or Watercourses of angle-iron, $4 \times 3\frac{1}{2} \times \frac{1}{2}$ in., running fore-and-aft on the upper deck and throughout the length of the battery on the main deck; remainder to be $9 \times 3\frac{1}{2} \times \frac{1}{2}$ in.

Waterway to Lower Deck of East India teak, worked as shown on the midship section.

Deck Flats—Upper Deck, $3\frac{1}{2}$ in. Dantzic deals.
Main Deck, Dantzic oak 4 in. thick.
Lower Deck, Dantzic deals $3\frac{1}{2}$ in. thick.

Ceiling, before and abaft Double Bottom, of red pine $2\frac{1}{2}$ in. thick.

Drainage, between the inner and outer bottom, and between the keel and the first longitudinal on the starboard side of the

ship, to be a wrought iron 12-inch drain pipe. In every compartment of the hold to be a drain or cistern formed in the inner bottom, its lower part resting upon and opening into the drain pipe. The water will be pumped from the drain pipe by the steam pump. On the port side of the keel a 5-inch pipe, also of wrought iron, is to be fitted through the double bottom. 5-inch pipes, similar to the above, are to be led from the longitudinal at the foot of the wing passages into the main drain pipes. These pipes to be carried down between the inner and outer bottoms, and through the holes in the longitudinals; those on the port side will have to pass through the vertical keel. Means are to be provided for filling each compartment with water by a nozzle, to which a hose may be attached, and a pipe leading above the water line for a vent.

THE "GREAT EASTERN" IN 1868.

In page 153 an account of the early stages in the progress of this remarkable vessel, at that time called the *Leviathan* is given. Ten years have elapsed since that account was written, and incredible sums of money have been expended in launching, completing, repairing, and altering her. The experiment was so gigantic, the vessel was so far removed from all competition with other ships, that an almost universal desire was felt that she should be a success, while an equally general conviction weighed on the minds of practical shipowners that, commercially, she must be a failure.

The *Great Eastern* has, however, been a source of great interest to the world at large, and to scientific men in particular. We have witnessed a confirmation of several important questions, some of which directly concern the object of this Work, and I may be excused if I enumerate some which are slightly foreign to it. A history of all the events connected with this ship would occupy a volume, and would not be devoid of interest.

But I may first allude to a point of some interest to myself. This ship on an outward voyage to New York, touched, as it was thought slightly, upon a rock; her double skin prevented the water from penetrating into the holds, so that she arrived safely at her destination. It was there, however, found that the damage was very extensive, and that she must be repaired;

but how could this be done where no graving dock or slip could receive her, and the tides were insufficient to allow her to be put ashore and left dry, as had been done at Milford Haven and at Liverpool. The Captain afterwards informed me that, having purchased this work at New York, he was enabled, from the drawings, to construct a large caisson exactly adapted to her form, by which men could go down and repair the damage.

This accident illustrates what was felt by all shipowners, that even a slight injury under water to a vessel so much in excess of all existing means for repairing her, must occupy a long time and cause a large outlay.

One point to be noticed relative to her great size (about five times that of any merchant vessel afloat even at the present time) is that her speed was very great in proportion to the indicated power of her engines. This was anticipated, and arises from two causes: first, because the area of surface for friction in the water does not increase in the ratio of the cubical contents of the ship; and secondly, because the increase of size renders the action of the waves less detrimental to her speed.

The action of this ship at sea has always been the subject of comment, many supposing that her size would reduce the motion so much as to take away all the horrors which landsmen experience in a gale of wind. In one respect this is realised; for while steaming head to wind, the pitching motion is only felt when the sea is long, and at all times is much less than that of an ordinary vessel; but in a beam sea the oscillations are described as being very great, though easy; indeed, the motion of every ship is guided by certain well-known rules dependent more on the position of the centre of gravity than on the external form or even her size.

Reflections upon the structure of the hull are, however, more in accordance with the subject of this work, and there are some points here that give valuable hints to naval architects. It is well known that the quantity of iron used in the hull is less in proportion to her measurement than in the ordinary iron ship, and yet she has gone through most severe trials without showing any symptom of weakness. The scantling of the plates and angle iron is given in page 156, and the form of the structure is illustrated in plates 22 to 24. By these it will be seen that the greater part of the upper deck is of iron, and cellular like the bottom; but this system is not carried to the ends, thus applying the greater strength to the centre part of the ship, and relieving the weight at the extremities. It is for the want of a

judicious adaptation of this kind that we have continued to load our ships with iron at the ends, to the serious diminution of strength in the structure as a whole, as well as an unnecessary addition of weight.

This ship also exhibits on a large scale a system now becoming very general. I allude to the absence of an external keel. This appendage to an iron ship had its origin, no doubt, in the custom of applying keels to wooden ships, and these almost always propelled by sails; serving the double purpose of giving additional stiffness longitudinally to the hull, and of counteracting the leeward pressure of the sails, which in the short ships of former times was necessary. In the *Great Eastern* there is no external keel, and the bottom is formed in its transverse section quite flat for several feet; so that when resting on a slip or on the ground, the vessel is supported on a broad base, and not on a keel. By this mode of building a ship, the sudden angle required in the plates of the garboard strake is avoided, and the cost of repairing ships injured in taking the ground is reduced. The late new ships built for the navy are without keels; but in all cases we assume that any reduction in strength caused by its omission is provided for in the internal keelson.

I have before objected to the great spaces left unsupported by ribs between the longitudinal stringers, and am glad to observe that Mr. Reed, in adopting the longitudinal system, has to a great extent obviated this evil.

By the description given above of the accident to the *Great Eastern* when on her passage to New York, we may suppose it probable that her safety, and, perhaps, that of many lives, was due to the double plating of the lower part of the hull. Many vessels have this protection, arising from the frequent use of water-ballast, as described in other places.

We see in this ship also a great triumph for iron as a material for ship-building; it is, perhaps, not too much to say that a vessel which should exhibit results such as have been witnessed in her, could not have been formed of timber on any known principle of building.

The *Great Eastern* has, however, not been built in vain; there is no doubt that her great size, enabling her at one time to receive a larger cargo than any other ship, was instrumental in laying successfully the Transatlantic cables, and thus completing a work of so much importance. It is to be hoped that additional employment in this way may be found for her.

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